DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT D-77-29

AN ASSESSMENT OF PROBLEMS ASSOCIATED WITH EVALUATING THE PHYSICAL, CHEMICAL AND BIOLOGICAL IMPACTS OF DISCHARGING FILL MATERIAL

by

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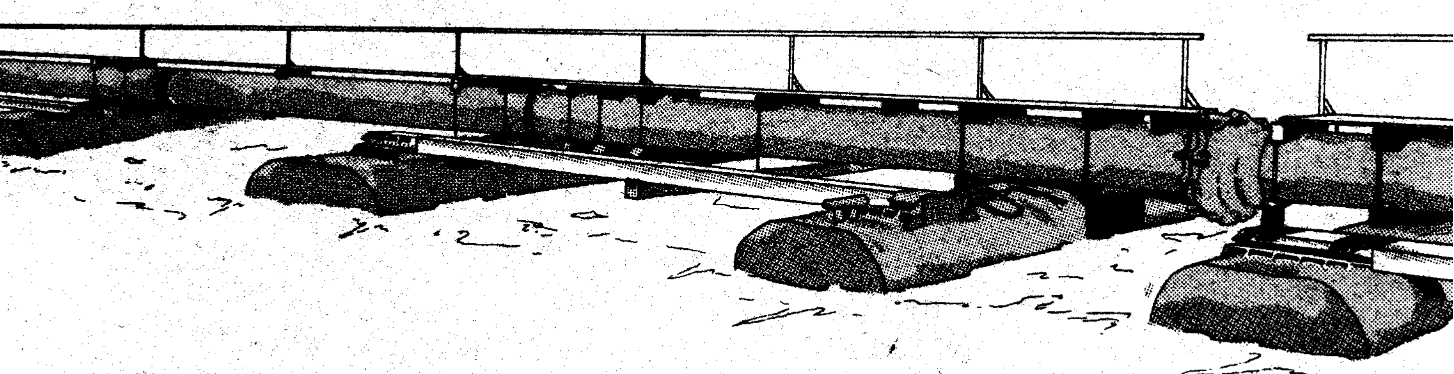

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1. Section 404 of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, designates the U. S. Army Corps of Engineers as the agency to issue permits for the discharge of dredged or fill material into navigable waters at specified disposal sites. The guidelines for the ecological evaluation of the discharge of dredged or fill material published by the Environmental Protection Agency (EPA) in the Federal Register (Volume 40, No. 1973, Friday, 5 September 1975) give general descriptions of these evaluations. The Dredged Material Research Program (DMRP), a broad multifaceted investigation of the environmental issues concerning the discharge of dredged material, bears some indirect relationship to fill material discharge activities but did not directly address potential problems resulting from the discharge of fill material. While the EPA guidelines apply equally to dredged or fill material, the testing and evaluation procedures identified in the Federal Register are not designed to account for the physical/chemical and biological interactive effects of fill material. Consequently, through DMRP-related funding, "An Assessment of Problems Associated with Evaluating the Physical, Chemical, and Biological Impacts of Discharging Fill Material" was initiated.

2. The report transmitted herewith is a multidisciplinary effort to conduct a state-of-the-art assessment of problems associated with evaluating the physical, chemical, and biological impacts of discharging fill material. The focus was directed to two broad categories: (a) administrative/procedural problems and (b) technical problems associated with impact prediction and assessment. Two broad tasks were identified to accomplish the study objective: basic information gathering and assessment of problems and needs. A weighted-ranking technique was used to establish the priorities of the identified problems and needs.

3. Contacts with 14 Corps offices, 10 other Federal agencies, and 50 state water resource agencies were used to identify the concerns related to the permitting of fill material discharge. Results of the survey identified administrative/procedural needs that included, in decreasing

order of priority, scientific rationale for permit issuance, increased personnel and laboratory resources, increased communications, surveillance of permit compliance, and information dissemination. A literature survey to determine technical deficiencies showed potential physical impacts that included changes in infiltration and flow regimes, destruction/alteration of natural or man-made habitat, and creation of habitats. Chemical impacts were found to result from the release of suspended solids, organics, nutrients, and toxic substances. Biological impacts ranged from physical barriers to fish migration to complete smothering of entire wetlands. The effects of leachates on aquatic biota were found to be complex and diverse ranging from no measurable changes to acute toxicity.

4. The information and data published in this report are a valuable foundation for planning fill activities--a foundation to be augmented by more meaningful and comprehensive evaluation procedures and guidelines. Future work in this area should include impact quantification and modeling, construction techniques and control measures for impact minimization, verification of predicted long-term impacts, basic chemical and biological interactions and effects, applicability of dredged material disposal findings, characterization of wetlands, and magnitude of fill discharge operations. It is expected that the assessment presented herein will be of significant value to those persons concerned with CE fill material permit programs.

JOHN L. CANNON
Colonel, Corps of Engineers
Commander and Director

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Fill materials can be natural (soil, rock, or sand) or man-altered (dredged material, solid wastes, or residues), with projects involving usage including property protection, causeway/roadfills, and site development. Potential environmental impacts are regulated by permits based on Section 404 of PL 92-500. This study focused on problems associated with evaluating environmental changes resulting from fill material discharges. A weighted-rankings technique was used to established priorities of permitting (administrative) concerns and technical deficiencies.

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20. ABSTRACT (Continued)

Permitting concerns were identified by contacts with 14 Corps Offices, 10 Federal agencies, and 50 state water resource agencies. Administrative/procedural needs identified in this study, in decreasing priority, include scientific rationale for permit issuance, increased personnel and laboratory resources, increased communications, surveillance of permit compliance, and information dissemination. Testing of proposed fill material may be required to establish engineering-related properties, identify leachates, and evaluate their biological impacts.

A literature survey was conducted to determine technical deficiencies. Potential physical impacts found include changes in infiltration and flow regimes, destruction/alteration of natural or man-made habitats, and creation of habitats. Chemical impacts were found to result from the release of suspended solids, organics, nutrients, and toxic substances. Biological impacts ranged from physical barriers to fish migration to complete "smothering" of entire wetland areas. The effects of leachates on aquatic biota were found to be complex and diverse, ranging from no measurable changes to acute toxicity. Technical research needs identified in decreasing priority include studies on impact quantification and modeling, construction techniques and control measures for impact minimization, verification of predicted long-term impacts, basic chemical and biological interactions and effects, applicability of dredged material disposal findings, characterization of wetlands, and magnitude of fill discharge operations.

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SUMMARY

Discharge of fill material means the addition of fill material into navigable waters for the purpose of creation of fastlands (landfills), elevation of land beneath navigable waters, or for impoundment of water. Fill material discharges in wetland areas are of particular concern due to the potential environmental impacts. Both natural materials (soil, rock, and sand) and man-altered materials (dredged material, municipal solid wastes and incinerator residues, coal ash, mine tailings, and various sludges) can be used as fill.

Examples of projects involving the use of fill material include dams and impoundments; site development for recreational, industrial, commercial, residential or other uses; causeways or road fills; property protection facilities such as dikes, levees, and bulkheads; and pollution control facilities such as sanitary landfills. Offshore developments include airports, artificial islands, and port facilities.

Millions of acres of estuarine habitat have already been lost or modified as a result of activities to create new land for development or to build structures for protection from the elements. Filling is projected to continue to be or become a problem in about two-thirds of the nation's 678 estuaries. Regional requirements for future landfills (fastlands) in coastal areas are projected to exceed available dredged material volumes. Inland usage of fill materials is also expected to increase as a result of population increases and concomitant pressures for recovery and use of marginal lands in urban areas.

The potential environmental impacts of discharging fill materials have been of increasing concern within recent years. These discharges are currently regulated by Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). The purpose of the research project reported herein was to conduct a state-of-the-art assessment of problems associated with evaluating the physical, chemical, and biological impacts of discharging fill material. Problem areas included administrative/procedural concerns and technical information deficiencies. A weighted-rankings technique was used to establish the priorities of the identified problems and needs.

The key requirement of Section 404 is the issuance of permits by the Corps of Engineers for fill discharge into navigable waters at specified sites. The definition of navigable waters has been considerably expanded in recent years, with the current Corps authority under Phase III of the program extending to

stream headwaters with flows greater than 5 cubic feet per second (cfs). Requests for permits are to be rejected when it is shown that the fill material discharge will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishing areas (including spawning and breeding areas), or wildlife or recreational areas.

The administrative/procedural concerns are primarily related to the permitting process. In order to identify these concerns, visits were made to fourteen District/Division Offices of the Corps, visits and phone contacts were made with ten other Federal agencies and related organizations, and a telephone survey of the water resources agency in each of the 50 states was conducted. Further identification was accomplished at a project workshop attended by the 12-member team from the University of Oklahoma; several invited persons from the Corps, Environmental Protection Agency, Fish and Wildlife Service, and Federal Highway Administration; and one consultant from Texas A&M University. The ranking of the identified administrative/procedural problems is presented as follows, in decreasing order of priority:

1. Scientific rationale for permit issuance needs to be developed, particularly for expediting general permits as well as permits for those projects considered to have minor environmental impacts.

2. There is a need for increasing the basic personnel and laboratory resources within all Corps District Offices in order to meet the demands of increasing numbers of permit applications being received during Phase III of the Section 404 permit program.

3. There is a need for increased internal communications within the Corps relative to recognition of work accomplishments in the Section 404 program area, provision of administrative/technical training, and dissimination of information to Division/District Offices and between Division/District Offices and the Office, Chief of Engineers (OCE).

4. There needs to be increased efforts to improve institutional relationships between the Corps and the 50 states, as well as between the Corps and other Federal agencies having responsibility or interests in the Section 404 program. The primary need is for information communication and continuing coordination.

5. There is need for a program to provide continuing surveillance and enforcement of compliance/non-compliance with Section 404

requirements. There is no follow-up verification that the stipulations contained in permits will be actually followed during construction and operation of fill discharge projects.

6. There is need for information dissemination at all levels on changes in operational policies. Information on court decisions and their implications, as well as clarification of conflicting responsibilities between old and new legislation needs to be provided in a timely fashion.

Technical information is needed in the permitting process to properly predict and assess the physical, chemical, and biological impacts of discharging fill material. Testing of proposed fill material may be required to establish certain engineering-related properties, identify physical and chemical components which may leach during or following placement, and evaluate potential biological impacts of the leachates, including toxicity or stimulation.

In order to identify available technical information as well as delineate data gaps and information needs, an extensive literature survey was conducted. The review of pertinent published literature was focused on (1) the physical, chemical, and biological impacts of fill discharge, and (2) planning, design, and construction measures for impact minimization. A review of existing environmental impact assessment (EIA) methodologies which have been applied, or are potentially applicable, to fill discharge projects was also accomplished.

Six case studies were also identified and visits were made to four of them to visually determine the environmental impacts or lack thereof. Visits were made to an industrial site using dredged material and quarry rock, a residential/commercial development using dredged material, a highway project using earthfill and highway solid wastes, and a sanitary landfill comprised of municipal solid wastes.

Available technical information is summarized in Table S-1 relative to the types of fill materials used for five categories of projects. The most frequently occurring types of projects are associated with property protection, causeway/roadfills, and site development. Table S-2 summarizes the previous and anticipated future usage, impacts of concern, and recommended testing for six categories of fill material.

Table S-1. Summary of project types and associated fill materials

Type of Project	Frequency*	Type of Fill Material Used					
		Earth fill	Dredged material	Solid wastes	Coal ash	Mine tailings	Other (sludges)
Dam	1	X					
Site development	3	X	X		X	X	
Causeway/roadfill	4	X	X	X	X	X	
Property protection	5	X	X				
Pollution control	2			X			X

* 1 = least, 5 = most

Table S-2. Summary of environmental impacts and recommended testing

Type of	Usage*		Impacts of Concern**			Recommended Testing***				
Fill Material	Previous	Future	Physical	Chemical	Biological	A	B	C	D	E
Earth fill	E	E	1		1	X				
Dredged material	M	I	2	2	2		X	X		X
Solid wastes (municipal)	L	M	1	2	1		X		X	
Coal ash	L	M	1	3	2		X		X	X
Mine Tailings	L	M	2	3	3		X		X	X
Other (sludges)	L	L	3	2	3		X		X	X

* E = extensive, I = intermediate, M = modest, L = low.

** 1 = minor impacts, 2 = intermediate impacts, 3 = major impacts.

*** X denotes testing is recommended; A = conventional tests for engineering properties, B = modified tests for engineering properties, C = Elutriate Test, D = modified Elutriate Test, E = bioassay tests.

Earth fill (soil, sand, gravel) and dredged material are the most frequently used fill materials. The impacts of concern reflect the potential importance of resultant environmental changes. More extensive testing is recommended for those fill materials exhibiting the greatest potential impacts.

Potential physical impacts resulting from fill material discharge include changes in infiltration, flow regimes, water levels and erosion/deposition patterns; destruction/alteration of natural or man-made habitats; and creation of habitats. This listing does not preclude the simultaneous occurrence of several physical impacts.

Potential chemical impacts result from the release or sorption of chemicals or solids (including suspended solids, organics, nutrients, and toxic substances) to or from adjacent waters and the fill site. These processes may then result in changes in pH and concentrations of carbon dioxide and dissolved oxygen. These consequences of fill discharge may further include shifts in the rates and/or extents of chemical reactions.

The biological impacts of fill material discharge result from precursor physical and chemical changes. General ecosystem changes can result from destruction/alteration of existing habitats as well as the creation of new habitats. The mechanisms of change can range from physical barriers to the migration of anadromous fish and other aquatic animals to the "smothering" of entire wetlands areas. Changes in flow regimes and water levels can also cause undesirable biological consequences. The effects of fill-released pollutants on the biota of navigable waters are very complex and diverse. They range from no measurable effect to acute toxicity. Intermediate effects include stimulation, inhibition, and bioaccumulation. Information is available on the response of aquatic plants and animals to changes in turbidity, suspended solids, sediment, organic material, nutrients, toxic substances, pH, carbon dioxide, and dissolved oxygen.

Based on the literature review, case studies, and discussions at the project workshop, technical information deficiencies were delineated. The ranking of the identified technical problems and needs are presented as follows, in decreasing order of priority:

1. There is a need for extensive studies related to prediction and assessment of the impacts of fill material discharge on the physical, chemical, and biological environments. Included herein are technical needs for impact identification, quantification, and predictive modeling.

2. There is need for research on various construction techniques which could be utilized to minimize the impact of fill material discharge. Included should be studies of the response of various materials once they are placed in a fill.

3. Additional research is needed to identify control measures for minimizing impacts, as well as to develop monitoring methods for evaluating these control measures.

4. There is need for research to verify predicted impacts. This would include long-term monitoring of water quality in the vicinity of fill discharges, as well as possible adjustment of predictive methodologies.

5. Since many of the impacts from fill material discharge are related to chemical interactions and effects, there is need for basic research on many chemical processes which occur within the aquatic environment.

6. Since additional impacts from fill material discharge are related to biological interactions and effects, there is need for basic research on many biological processes which occur within the aquatic environment.

7. Due to the extensive research program conducted for dredged material, there is need for information on the applicability of these research findings to the general problem of prediction and assessment of the impacts from fill material discharge.

8. There is need for basic information and definition associated with wetlands, as well as characterization of numerous types of fill material.

9. There is a need for a definitive study on the current magnitude of fill discharge operations, the uses of filled areas, and the types of fill materials involved. This information also needs to be projected into the future in order to ascertain the long-term concerns.

In summary, major impacts on the physical, chemical, and biological environment can occur as a result of fill material discharge. Administrative/procedural problems exist with the Section 404 permitting procedure operated under the jurisdiction of the Corps. While technical information does exist regarding the environmental impacts of various types of fill material used in a variety of projects, there are major information deficiencies relative to impact prediction, assessment, and mitigation. Accordingly, additional research needs to be conducted in order for the Corps to more effectively administer the Section 404 permit program of PL 92-500.

PREFACE

This report was prepared under Contract No. DACW39-76-C-0128 between the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, and the University of Oklahoma, Norman, Oklahoma. It represents the summary of a state-of-the-art study of the problems associated with evaluating the physical, chemical, and biological impacts of discharging fill material.

The principal author is Dr. Larry Canter, Director and Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma. Acknowledgement is given to the following persons who contributed to the preparation of individual sections: Part III --- Dr. Edwin Klehr, Professor, Dr. Leale Streebin, Professor, and Mr. Gary Miller Graduate Student; Appendix A --- Mr. Darrell Cornell, Graduate Student; Appendix B --- Dr. Klehr; Appendix C --- Mr. Miller; Appendix E --- Dr. Streebin; and Appendix G -- Dr. Joakim Laguros, Professor. Other research team members included Dr. James Harp, Professor, Dr. James Robertson, Associate Professor, and the following graduate students --- Mr. James Loud, Mr. Abbass Shirazi, Mr. Keith Copeland, and Mr. Fred Parvizian. This report was typed by Mrs. Kristi Smith, Ms. Susan Wilkerson, and Mrs. Madelon Carmack.

Contract Managers were Dr. Robert Engler and Dr. John Keeley, Environmental Effects Laboratory, WES.

Directors of WES during preparation of the report were COL G. H. Hilt, CE, and COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

The U. S. customary units of measurement used in this report can be converted to metric units as follows:

Multiply	By	To Obtain
inches	2.54	centimetres
feet	0.3048	metres
miles (U. S. statute)	1.609344	kilometres
square miles	2.589988	square kilometres
acres	4046.856	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
gallons	0.003785412	cubic metres
acre-feet	1233.482	cubic metres
cubic feet per second	0.02831685	cubic metres per second
tons (short)	907.1847	kilograms
pounds (force) per cubic foot	0.1571	kilopascals per metre
pounds (force) per square inch	6.894757	kilopascals
pounds (force) per square foot	47.88026	pascals
tons (force) per square foot	95.76052	kilopascals

AN ASSESSMENT OF PROBLEMS ASSOCIATED WITH EVALUATING THE PHYSICAL, CHEMICAL, AND BIOLOGICAL IMPACTS OF DISCHARGING FILL MATERIAL

PART I: INTRODUCTION

The Problem

1. The potential environmental impacts of discharging dredged or fill material have been of increasing concern within recent years. These discharges are currently regulated by Section 404 of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972. The key requirement of Section 404 is the issuance of permits for discharge into navigable waters at specified disposal sites. Requests for permits are to be rejected when it is shown that the discharge of dredged or fill material will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), or wildlife or recreational areas.

2. In order to fulfill the responsibilities of Section 404, both the U. S. Army Corps of Engineers and the Environmental Protection Agency (EPA) have issued interim guidelines. The Corps published administrative procedures, "Permits for Activities in Navigable Waters or Ocean Waters" (Federal Register, Vol. 40, No. 144, Friday, 25 July 1975), that specified a phased implementation schedule which has continually increased the Corps' jurisdiction over fill material to include all navigable waters of the United States by 1 July 1977. The EPA guidelines for evaluating the impacts of dredged or fill material, "Navigable Waters: Discharge of Dredged or Fill Material," (Federal Register, Vol. 40, No. 173, Friday, 5 September 1975), indicate that applicants for permits to discharge dredged or fill material will be provided specific guidance by the Corps District Engineer on appropriate methods for predicting the environmental impacts of their operations.

3. In order to develop guidance for the discharge of dredged material, the U. S. Army Engineer Waterways Experiment Station (WES)* was assigned to administer the Dredged Material Research Program (DMRP). Among its objectives, this comprehensive, nationwide program seeks to provide definite information on the environmental effects of dredging and dredged material disposal operations

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* Vicksburg, Mississippi.

in all environmental situations. While the EPA guidelines apply equally to dredged or fill material, the identified testing and evaluation procedures are not designed to account for the physical/chemical and biological interactive effects of fill material. Accordingly, the need for a definitive study on the physical, chemical, and biological impacts resulting from the discharge of fill material was recognized.

Objective

4. The objective of this study was to conduct a state-of-the-art assessment of problems associated with evaluating the physical, chemical, and biological impacts of discharging fill material. The focus was directed to two broad categories: (1) administrative/procedural problems and (2) technical problems associated with impact prediction and assessment.

Approach

5. To accomplish the study objective, two broad tasks were identified: basic information gathering and assessment of problems and needs.

Basic information gathering

6. Table 1 identifies various activities conducted during the basic information gathering task. Each activity is further identified relative to its provision of information for either administrative/procedural or technical concerns. Each activity provided input into both areas.

7. The literature review on the environmental impacts resulting from the discharge of fill material consisted of a thorough search of library resources as well as the utilization of numerous information storage and retrieval systems.* The literature review identified areas of knowledge with regard to the physical, chemical, and biological impacts of the discharge of fill material. Information from this review is summarized in Parts II and III.

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* The systems which were queried included GIPSY (Department of the Interior), Smithsonian Science Information Exchange, Highway Research Information Service, Oklahoma Environmental Information and Media Center (Ada, Oklahoma), Solid Waste Information System (Cincinnati), and the Conservation Resources Information System (Soil Conservation Service).

Table 1. Activities associated with basic information gathering task

Activity	Area of Concern* Administrative/ Procedural	Area of Concern* Technical
1. Conduction of literature review on environmental impacts	m	M
2. Review of legal and legislative history	M	m
3. Contacts with Corps offices	M	m
4. Contacts with other Federal agencies	M	m
5. Conduction of state survey	M	m
6. Review of environmental impact assessment (EIA) methodologies	m	M
7. Review of selected permit applications and environmental impact statements (EIS's).	m	M
8. Analysis of selected case studies	m	M
9. Conduction of literature review on impact minimization	m	M

*m = minor input
M = major input.

8. The legal/legislative history associated with dredging or filling was reviewed to provide a background for the requirements of Section 404 and to identify major administrative/procedural problems from the standpoint of the legislation itself. Some attention was devoted to various amendments proposed for Section 404. A summary of these findings is in Appendix A. Appendix B has a discussion of the pertinent guidelines relating to fill discharge.

9. Personnel at the Office of the Chief of Engineers and at fourteen District and Division offices of the Corps were contacted regarding various administrative/procedural and technical problems associated with compliance with Section 404 of Public Law 92-500. Other Federal agencies contacted regarding various reference sources and experiences relative to the discharge of fill material included the Bureau of Reclamation, EPA, Federal Highway Administration, Bureau of Land Management, Marine Fisheries Service, Fish and Wildlife Service, Bureau of Mines, Coast Guard, Soil Conservation Service, Geological Survey, and Department of Housing and Urban Development. Appendix C summarizes the findings of contacts with the Corps of Engineers and other Federal agencies.

10. A telephone survey of the water resource agency in all fifty states was conducted to obtain information relative to their response to Section 404 requirements. Information requested included technical references/studies and identification of problems associated with administrative/procedural or technical aspects of Section 404. The telephone survey and findings are also detailed in Appendix C.

11. The sixth activity was a review of EIA methodologies. Since the effective date of the National Environmental Policy Act (1 January 1970), over 50 methodologies have been developed. No single methodology has been developed for all projects involving the discharge of fill material, although key features of several are potentially useful. The methodology most closely matching the needs for describing the physical, chemical, and biological impacts resulting from discharge of fill material was developed by Battelle Columbus Laboratories* for dredging (Battelle Memorial Institute, 1974). A summary of this review is contained in Appendix D.

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* Columbus, Ohio.

12. The seventh activity consisted of a review of selected permit applications, statements of findings, and environmental impact statements (EIS's) relative to the 84 environmental items specified in the environmental impact assessment (EIA) methodology developed for dredging (Battelle Memorial Institute, 1974). Eleven permits/statements of findings, and 42 environmental impact statements were reviewed to provide documentation of what has been previously done in identifying and describing the potential impacts of fill material discharge. The selected permits, statements of findings, and EIS's were identified from contacts with Corps personnel and a review of the 102 Monitor published by the Council on Environmental Quality. A summary of this review is also contained in Appendix D.

13. The eighth activity was an analysis of selected case studies. Six projects were examined as examples of the identification and description of physical, chemical, and biological impacts from fill material projects: the Richard B. Russell Dam, South Carolina; Marco Island, Florida; Kaiser Steel Company, Seattle, Washington; highway development in California; Maumee diked disposal area, Toledo, Ohio; and a landfill in Beaumont, Texas. Four of these projects were visited, and the key administrative/procedural and technical concerns are summarized in Appendix E.

14. The final activity in the basic information gathering task was a literature review of various measures which could be taken to minimize the environmental impacts of fill discharge projects. Appendix F addresses general planning/design constraints and erosion control, while Appendix G contains information on engineering properties of fill materials and specific design considerations.

Assessment of problems and needs

15. The second major task was an assessment of problems and needs identified from the basic information gathering task. Activities associated with this task included visits to WES to solicit information and assess preliminary findings and weekly meetings of the research team to coordinate work efforts and discuss and assess problems and needs. The key activity was a workshop in Dallas, Texas, to present the study mechanics, delineate administrative/procedural and technical problems not previously identified, and discuss identified problems and needs. This workshop was attended by the 12-member team from the University of Oklahoma; several invited persons

from the Corps of Engineers, EPA, Fish and Wildlife Service, and Federal Highway Administration; and one consultant from Texas A&M University. This task concluded with an establishment of priorities of problems and needs through the use of a weighted-rankings technique. The method permitted ranking of administrative/procedural problems and problems associated with impact prediction and assessment. A summary of this task is in Part IV.

PART II: BACKGROUND FOR STUDY

16. This part contains discussions of basic definitions and concepts concerning fill material, the magnitude of recent filling activities in the United States, examples of fill discharge projects, and examples of man-altered fill materials.

Basic Definitions and Concepts

17. Basic definitions and concepts are needed with regard to what is fill material, what constitutes the discharge of fill material, and what comprises the environmental impacts resulting therefrom.

Fill material

18. Fill material means any pollutant used to create fill in the traditional sense of replacing an aquatic area with dry land or changing the bottom elevation of a water body for any purpose. Certain types of material are specifically excluded from this definition by the EPA guidelines (Federal Register, Vol. 40, No. 173, Friday, 5 September 1975), and these are

> "(i) Material resulting from normal farming, silviculture, and ranching activities, such as plowing, cultivating, seeding, and harvesting, for the production of food, fiber, and forest products;
>
> "(ii) Material placed for the purpose of maintenance, including emergency reconstruction of recently damaged parts of currently serviceable structures such as dikes, dams, levees, groins, riprap, breakwaters, causeways, and bridge abutments or approaches, and transportation structures."

19. Examples of materials used as fill, and which fit the above definition, include natural materials (soil, rock, and sand) and man-altered materials (dredged material, municipal solid wastes, municipal incinerator residue, utility coal ash, mine tailings and sludges from water and sewage plants, pollution control systems, and industrial processes). Man-altered materials will be discussed in the last section of this part.

20. The definition of fill material includes the word pollutant. Whether fill materials are used singly or in combination, they exhibit certain properties that are important in determining potential impacts. One of the key issues involved in the definition of fill material is related to subsequent requirements for testing/evaluation to identify potential environmental impacts. One viewpoint would be to only approve the discharge of nonpolluted

fill material. Usage of nonpolluted materials in limited quantities could conceivably lead to elimination of requirements for discharge permits for these types of materials. Usage of polluted fill material should in all cases require a permit, with the fill material being subjected to various testing/ evaluation procedures. If more precise definitions could be developed relative to polluted and nonpolluted materials, the general work load required for processing and issuance of permits would be reduced.

Discharge of fill material

21. Discharge of fill material means the addition of fill material into navigable waters for the purpose of creating fastlands (landfills), elevation of land beneath navigable waters, or for impoundment of water. According to the location for fill material discharge, fill can be underwater entirely, partly in water and partly out of water, or all out of water, that is, on dry land. Discharge of fill material associated with underwater locations, or partly in and partly out of the water locations, can be made into fresh water or seawater or some combination of these two in the estuarine zone. Two major physical configurations of fill can be defined: area fills and line fills. Area fills are those basically directed toward creation of continuous land, while line fills are related to corridor-type projects. Table 2 summarizes various categories of fill material discharge. If the discharge of fill material could be defined relative to both type of material and size of project, the number of permit applications and resultant required permits would be minimized.

Potential impacts of discharged fill

22. A key concern relative to the discharge of fill material is the resultant impacts which will occur on the physical, chemical, and biological environments. Impact denotes the change, either beneficial or detrimental, that occurs in a particular environmental factor as a result of fill material discharge.

23. Impact assessment involves both prediction of change as well as interpretation of the effect of that change. Prediction of change encompasses consideration of type (what) and quantity (how much), while interpretation focuses on the magnitude (scale) of the change and professional judgment of its importance.

24. Impact categories. There are many ways to categorize impacts from the discharge of fill material. One viewpoint would be to consider impacts on

Table 2. Categories of fill material discharge

Project Type	Location*	Physical Configuration
Structures and impoundments -- placement of fill that is necessary to the construction of any structure; the building of any structure or impoundment requiring rock, sand, dirt or other pollutants for its construction;	A, B	Area, Line
Site development -- site-development fills for recreational, industrial, commercial, residential, and other uses;	A, B	Area
Causeways/road fills -- causeways or road fills;	A, B	Line
Property protection -- dams and dikes; artificial islands, property protection and/or reclamation devices such as riprap, groins, seawalls, breakwalls, and bulkheads and fills; beach nourishment; levees;	A	Area, Line
Pollution control and other -- sanitary landfills; fill for structures such as sewage treatment facilities, intake and outfall pipes associated with power plants, and subaqueous utility lines; and artificial reefs.	A, B, C	Area, Line

*Location A = part in and part out of water
Location B = dry land
Location C = underwater

various components of the environment, including the physical-chemical, biological, cultural, and socioeconomic environments.

25. Impacts can also be considered relative to space or geographic distribution. Certain impacts resulting from the discharge of fill material will be site specific; that is, they will occur at the site where the discharge takes place. Other impacts will occur in the vicinity of the fill area, while still additional impacts may occur downstream. The magnitude of the changes will vary with spatial distribution, and interpretation of their importance will vary depending upon the location of occurrence.

26. Impacts can also be described relative to the various time phases associated with projects. Certain impacts will occur during the physical discharge of the fill material (construction phase), while other impacts may occur from subsequent use of the fill area.

27. Impacts can also be categorized according to whether they are direct or indirect. Direct effects are mainly related to the construction phase as well as direct usage of the completed fill area. Indirect impacts occur as a result of growth-related changes in land uses in the vicinity of the fill area.

28. Finally, impacts can be categorized as to their potential for reversibility. Some impacts may be reversible while others may be irreversible.

29. Environmental impact relationships. Figure 1 depicts the relationships between physical, chemical, and biological impacts resulting from the discharge of fill material. Physical impacts result from the discharge of fill material (primary), or from resulting impacts in the chemical and biological environment (secondary). Some physical impacts may also result from other precursor physical impacts. Chemical and biological impacts can also occur via primary and secondary routes. Figure 2 depicts the impacts from the discharge of fill material in a fashion which suggests that the biological impacts represent composite indicators for previously occurring physical and chemical impacts.

Magnitude of Filling Activities in the United States

Previous activities

30. Most estuarine areas of the United States have been modified more or less severely by the various activities of man in dredging and filling operations. It is noted that 23% of the estuarine areas have been severely

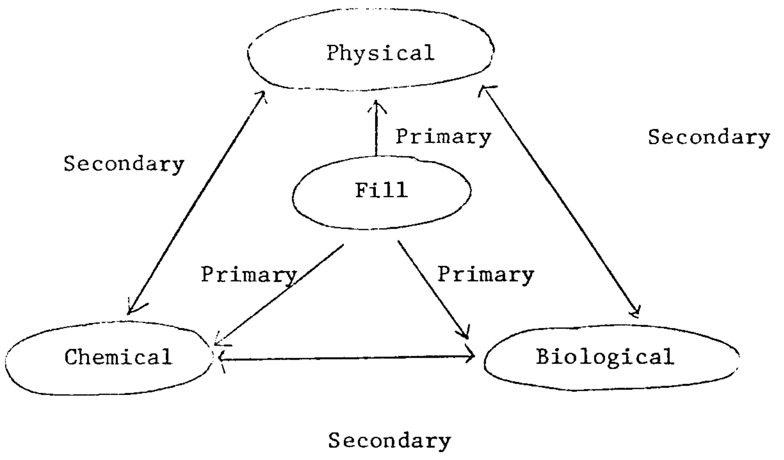

Figure 1. Relationships between physical, chemical, and biological impacts

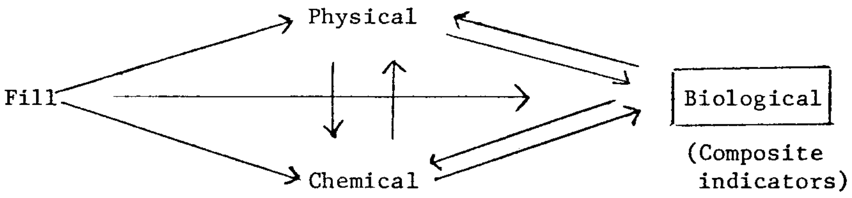

Figure 2. Biological impacts as composite indicators

modified, while 50% have been changed to a moderate extent (U.S. Department of the Interior, Vol. 1, 1970). Between 1950 and 1969, nearly 666,000 acres, or 4%, of the fish and wildlife habitat was lost to filling and dredging operations (U.S. Department of Interior, Vol. 2, 1970).

31. In 1968, over 25,000 acres were altered by dredging and filling and over one-half of this was associated with filling activities for commercial, industrial, institutional, housing, and recreational uses. For the period 1950 through 1969, losses of estuarine habitat to dredging and filling in three key coastal states (New York, Florida, and California) amounted to 234,000 acres. Nearly a third of this acreage was filled for industrial and commercial development (U.S. Department of the Interior, Vol. 2, 1970).

32. The magnitude of filling activities also includes estuarine modifications associated with the construction of miscellaneous structures such as jetties, dikes, breakwaters, piers, and causeways. These modifications result in changes in circulation patterns and water movement within the estuarine zone, thus changing the resultant chemical and biological environments.

33. Although millions of acres of estuarine habitat have already been lost or modified as a result of activities to create new land for development or to build structures for protection from the elements, more loss is expected as greater proportions of the population move to coastal areas.

Future considerations

34. Forecasts of future estuarine environmental problems were developed by personnel of the Fish and Wildlife Service with assistance from personnel of cooperating state agencies (U.S. Department of the Interior, Vol. 2, 1970). A total of 678 individual estuaries considered to be important to fish and wildlife sources were rated as to the status and prospects of their use/conflict and other environmental problems. Filling was projected to be a problem in 430 of the 678 estuaries, and dikes and levees were identified as potential problems in 254 of the total.

35. An extensive study of coastal needs for landfills (fastlands) and construction materials conducted in 1973-1974 (Reikenis, Elias, and Drabkowski, 1974) evaluated regional requirements for landfills and construction materials. The study identified the potential uses of landfill relative to urban, economic, environmental, and recreational activities in coastal regions. The study provides detailed estimates for each region, but in general found that regional needs for landfills and construction material will vary substantially due to population shifts and economic growth. Regional needs will be

substantially in excess of available dredged material volumes; accordingly, substantial quantities of nondredged fill material (for example, sand and gravel) are projected as required for all regions.

Examples of Fill Discharge Projects

36. Extensive land reclamation and fill discharge projects in Europe, especially in the countries along the North Sea, date back to about A.D. 900 (Davis and Nudi, 1971). Holland's elaborate system of dikes and canals enclose nearly 2 million acres of farmland, pastures, and sites for towns and cities (Lord, 1974). Reclamation is still intensely pursued, and very estensive projects, such as the Zuider Zee Development, will add over 1.5 million acres by about 1980.

37. Although the discharge of fill material is not limited to coastal areas in the United States, fill activities have focused on the creation of additional lands along the sea coast. The concentration of people and wealth around harbors has produced the need for more desirable land along the coast and more access to the sea for leisure and pleasurable pursuits (Skinner and Turekian, 1973).

38. Fill discharge projects in the United States can be divided into two categories based on location (onshore and offshore). This section presents examples of existing and proposed onshore and offshore projects involving the discharge of fill material.

Onshore fill projects

39. Reclamation of land has occurred in many major coastal cities and areas in the United States since the 1600's. Extensive fill areas constitute portions of current-day Manhattan Island in New York City (Rutledge, 1970), Boston (Teal and Teal, 1969), and Cambridge (Rutledge, 1970). Examples of onshore projects will be cited for New Orleans (Gagliano, 1973) and Miami Beach (Dzurik, 1976). In addition, large sections of Boca Ciega Bay in Florida (Taylor and Saloman, 1969), San Francisco Bay (Schoop, 1969), and Willapa Bay in Washington (U.S. Department of the Interior, Vol. 3, 1970) have been subjected to filling activities.

40. New Orleans. The urban growth of New Orleans which requires a reclamation project along the southern boundary of Lake Ponchartrain is a major example of filling in the United States. Presently, 6-1/2 miles of the project have been completed, including the New Orleans Lakefront Airport. The

project has been described as a multiuse development providing flood and erosion prevention as well as recreation, residential, and public facility sites (Gagliano, 1973).

41. Miami Beach. Another example of a fill project of major importance is the Miami Beach project in Florida, begun in 1913. This project included the transformation of a 200-foot-wide barrier island into a mile-wide tourist resort (Dzurik, 1976).

42. Boca Ciega Bay, Florida. Most coastal counties in Florida have been subjected to dredging and filling projects for a number of years, with the projects primarily concentrated in the middle and lower portions of the state. One of the most extensive fill projects is in Boca Ciega Bay, a narrow, coastal lagoon near Tampa. Ecological stress has been observed in Boca Ciega Bay as a result of hydraulic dredging and the creation of fingerlike fills for residential property. The ecological impacts are detailed in studies by Taylor and Saloman (1969) and Sykes (1971). Water circulation within the Bay has been partially obstructed, dredged silt and clay has been redeposited, and a large volume of domestic sewage has been introduced from the expanding bayside population. Most of the dredging and construction within Boca Ciega Bay occurred 15 to 20 years ago. Filling of 3500 acres has reduced the total area of Boca Ciega Bay by about 20% (Taylor and Saloman, 1969; Sykes, 1971). In a broader context Taylor (1970) has estimated that coastal development has drastically reduced or entirely eliminated biological production in about 20% of all coastal areas in Florida.

43. San Francisco Bay. Extensive filling has been practiced in San Francisco Bay for over a century due to the natural shallow characteristics of the Bay. About two-thirds of the original 680 square miles is less than 18 ft deep at low tide, and previous diking and filling of tidelands and marshes has reduced the original size to a little more than 400 square miles (Schoop, 1969).

44. A major fill project in San Francisco Bay was the construction of Treasure Island, which is a 400-acre artificial island constructed for use in the 1939 San Francisco Bay Exposition. Filling was initiated in 1936, and when it was completed in 1937, almost 30 million yd^3 of material had been placed in a shallow water area located in San Francisco Bay between San Francisco and Oakland (Pestrong, 1974).

45. The San Francisco Bay Conservation Development Commission released a plan in 1969 which recommended that filling of San Francisco Bay be limited

to only priority uses, with no future filling allowed for housing, solid waste disposal sites, and other low-priority projects (Schoop, 1969). The plan identified high-priority projects as ports, water-related industry, water-parks, marinas, beaches, fishing piers, and some airports and freeways.

46. One of the key environmental concerns relative to San Francisco Bay is the desire to minimize filling on marshes, mudflats, and adjacent salt ponds, since these areas are vital to fish and bird populations. Another environmental concern relates to the influence of Bay waters on the area climate. Bay waters moderate the extremes of hot and cold, and studies have indicated that converting more Bay surface to land would increase smog-producing temperature inversions in the area (Schoop, 1969).

47. Therefore, while extensive filling has occurred in San Francisco Bay, recent attention has focused on the long-term consequences of these activities, and future discharge of fill material will be limited to priority uses (Schoop, 1969).

48. Willapa Bay, Washington. Willapa Bay, located in Pacific County, Washington, is bounded by the Long Beach Peninsula, Pacific Ocean, and Cape Shoalwater on the west and by marshes, grasslands, and uplands in the other three directions. It is estimated that 6300 acres of Willapa Bay marshlands and tidelands have been reclaimed for agriculture, while another 300 acres have been reclaimed for industrial uses and highway purposes. In addition, in the late 1960's the Pacific Soil and Water Conservation District was urging the diking and reclaiming of an additional 6600 acres of tideland for pasture, hay, and silage production (U.S. Department of the Interior, Vol. 3, 1970).

49. Landfill projects in Willapa Bay have resulted in the destruction of nearshore shallow and highly productive areas important for estuarine and estuarine-dependent organisms, nutrient regeneration, and production of organic matter. Filling of portions of the Willapa Bay has already eliminated feeding and nesting areas for many species of fish and wildlife.

50. Continued draining, clearing, and filling of freshwater lowland swamps and ponds for housing developments is causing water-quality problems, altered drainage patterns, siltation, and increased concern to the oyster industry, fish and wildlife managers, and conservation interests.

Offshore fill projects

51. A number of offshore developments have recently been proposed or are under construction in coastal areas (Lord, 1974). Examples include offshore airports, artificial islands, and port facilities. A number of projects

now in the advanced planning or construction stage demonstrate that the trend is for offshore projects to be of larger size and greater diversity than in the past (Lord, 1974).

52. There are both beneficial consequences as well as potential adverse effects which can occur as a result of offshore development. Among the potential environmental benefits are filling of unsightly swamp areas, reduced shoreline erosion, improved flushing and circulation of coastal waters, expanded marine habitats, control of urban encroachments, less costly land in some cases, availability of large quantities of water for cooling and waste dispersion, reduced visual impact, and lessened noise impact. Conversely, offshore developments must be carefully planned to ensure minimal adverse effects from thermal pollution; destruction of valuable marine life; water, air, and noise pollution; dislocation of valuable or endangered species of wildlife; interruption of recreational uses; and despoiling of scenic beauty (Lord, 1974).

53. Offshore airports. There is a growing trend in airport developments utilizing offshore sites (Harza, 1972). A number of secondary offshore airports already exist, and serious consideration and planning is underway in several countries for major facilities. Major cities which have recently been or are presently giving serious consideration to offshore airports include New Orleans, Cleveland, Chicago, New York, Long Beach, Copenhagen, London, and Osaka (Harza, 1972).

54. Artificial islands. Another category of offshore projects involving the discharge of fill material are man-made islands used primarily for industrial purposes. Several islands have been built, and numerous others are in preliminary or final design (Riley, 1974, Anonymous, March 1975).

55. One of the key concerns associated with construction and use of offshore islands is related to minimizing potential environmental effects. Some suggested criteria for limiting impacts include the use of EPA water-quality standards for 26 inorganic and several organic compounds, less than a 10% change in local salinity, less than a 10% change in the ambient temperature of the ocean water around the island as a result of operations on the island, and less than a 10% change in the hydraulic mixing depth around the island (Anonymous, March 1975). The last criterion is of crucial consideration in maintaining proper light penetration in the marine environment. Two other criteria to minimize environmental effects include a recommendation that no

activity be undertaken that would result in more than an order of magnitude change in particulate solids that remain suspended for more than 24 hours, and that any heated water should be discharged in such a way as to be rapidly dispersed to meet local temperature standards.

56. Port facilities. Another example of the use of fill material involves the construction of onshore/offshore port facilities for large cargo ships. Such ports include Europort in Rotterdam (Goodier, 1973), the Port of Oakland in California (Nielsen, 1969), and the Port of San Francisco (Sembler, 1973).

57. Several other proposed ship facilities have been considered in recent years. In 1972, a study was made of the possible effects of construction and operation of a supertanker terminal on the New York Bight (McHugh et al., 1972). A conceptual design for a major port and harbor facility to be constructed on fill in the Gulf of Mexico was also developed in 1972 (Stogsdill and Willingham, 1972).

Man-Altered Fill Materials

58. Natural materials such as soil, rock, and sand have been primarily used in previous fill discharge projects, and their continued use is anticipated. Man-altered materials are being more frequently used, and the purpose of this section is to delineate and give examples of these materials. Man-altered materials encompass dredged material, municipal solid wastes and incinerator residue, coal ash, mine tailings, and various sludges.

Dredged material

59. The potential for using dredged material as fill is being investigated by several studies in the Dredged Material Research Program (WES). Because of the physical and chemical composition of dredged material, unique requirements for various land applications, and unique environmental features of particular potential sites, not all dredged material is suitable for all potential fill projects. Suitable uses include agricultural production, land improvement, wildlife habitat creation, recreation facilities, and industrial and residential landfill. Examples of these are cited by Lee, Engler, and Mahloch (1976).

60. Use of dredged material for creation of fill has been extensive in harbor construction and waterfront developments. There have been no major

environmental impacts from its use in construction of Air Force bases in Alabama and Florida (Lamar and Laier, 1976).

Municipal solid wastes

61. Use of municipal solid wastes as fill, including combinations of household refuse and construction and demolition debris, potentially requires procurement of a permit under Sec. 404 of Public Law 92-500. This material has been used to smooth irregular land contours, to fill gullies for reclaiming agricultural acreage, and to implement sanitary landfill/recreational projects. Examples of large-scale projects include a recreational complex at Virginia Beach, Virginia (Beck, 1973), and a recreational hill in a forest preserve in Illinois (Anonymous, August 1975). These projects require that leachates be collected and subjected to evaporation and treatment processes.

62. Another source of waste materials which could be used as fill includes construction and demolition wastes (Lee, Engler, and Mahloch, 1976). An example of the use of construction/demolition debris is in Toronto, Canada, where this debris is being mixed with dredged material to create an extensive shoreline park system and recreational island complex. In most cases, the only problem associated with this project is obtaining a uniform final grade.

63. The use of municipal waste materials such as crushed stone, sand, and gravel in highway construction has been proposed by Emery (1971). In the New York area, materials from a waste disposal site have been suggested as the primary fill material for construction of multi-purpose offshore islands. Use of this material would reduce environmental concerns.

Municipal incinerator residue

64. Municipal incinerator residue is beginning to be used as fill, with most of the incinerators being located in the eastern United States. Incinerator residue contains metals, glass, clinker material, ash, organics, ceramics, and stones. The primary concern associated with the use of this residue as fill is related to potential water pollution from the water-soluble portion of the residue. Depending upon the specific residue, from 1 to 6% is water-soluble (Hecht and Duvall, 1975). Some communities are beginning to use the residue as a filler for road construction (roadbed). It is anticipated that the use of municipal incinerator residue as a fill material will increase in the future, with the major uses related to highway construction.

Coal ash

65. Another material which has been used to a limited extent, and which is anticipated to increase in its uses as fill, is coal ash. The burning of coal produces an ash residue which is derived from the inorganic mineral constituents in the coal and the organic material not completely burned. In coal-burning utility boilers, the coal ash residue is collected from the bottom of the boiler (bottom ash) and from the air pollution control equipment through which the stack gases pass (fly ash). Over 46 million tons of coal ash were collected in 1972 by some 500 power plants in the United States (Hecht and Duvall, 1975). The distribution of power plants indicates that the largest concentration is in the middle Atlantic and eastern north-central states.

66. Since 1966, coal ash utilization has fluctuated around 15 to 16% of the total ash collected in the United States (Hecht and Duvall, 1975). Out of 46 million tons produced in 1972, approximately 7.5 million tons (16%) utilized for various purposes. The single largest application for coal ash is as a mineral filler material for concrete highways and other construction projects. Recent research results have indicated that large quantities of coal ash can be effectively used for agriculture, land reclamation, and water reclamation projects. Increased utilization of fly ash and bottom ash as a fill material for the development of marginal and/or submarginal land into desirable building sites offers a potential solution to mounting disposal problems for utility ash (Sikes and Kolbeck, 1973).

Mine tailings

67. Waste materials resulting from phosphate mining can be considerable, and through proper planning and management practices, these waste materials can be used to reclaim mined areas (Custred, 1975). Coal mine wastes can potentially be used as construction fill, lightweight aggregate, road base material, antiskid material for roads, brick manufacturing, and insulation material (National Academy of Sciences, 1975). Two general types of water pollution can result from mining waste piles: physical pollution such as siltation, and chemical pollution such as acid drainage.

Water treatment plant sludges

68. Water treatment plant sludges have some potential for use as a fill material (Faber and Taras, 1973). These sludges result from the application of chemicals such as alum, lime, and magnesium carbonate for purposes of water softening and coagulation. The traditional mode of disposal of water treatment

plant sludges has been to place the materials in either lagoons or land disposal sites. Disposal of these sludges in sanitary landfills yields several advantages (Hecht and Duvall, 1975). Mixing of the sludge with refuse could help the compaction of refuse in a landfill. Leaching has been reported when liquid sludge was used, but leaching can be controlled if dewatered sludge is applied. Sanitary landfills containing water treatment plant sludges can become potential fill sites with ultimate development. Another potential usage of water treatment plant sludges which might involve the Sec. 404 permit program includes the application of softening plant sludges in strip-mined areas for land-reclamation purposes. The lime sludge will reduce acid drainage and aid in reclaiming acid-bearing soils. Although specific information on application rates is not available, it is believed that large quantities of sludge can be absorbed in strip-mined areas (Hecht and Duvall, 1975).

Sludges from pollution control systems and industrial processes

69. Sludges from municipal sewage treatment plants have been discharged into sanitary landfills for many years. State public health programs identify the following problems associated with landfill sludge disposal: increased leachate production from liquid sludge; odors; adverse public opinion; equipment damage and compaction difficulties; nuisance and potential spread of pathogens by vectors; and difficulty in sludge burial (Stone, 1974). Since sewage sludge can be disposed in sanitary landfills and since sanitary landfills may be subject to Sec. 404 permit requirements, there is concern regarding sewage sludge as a potential fill material.

70. A three-year investigation of the environmental and economic effects of disposing liquid sewage sludge and septic tank pumpings into a sanitary landfill has been recently completed (Stone, 1974). The study concluded that sanitary landfills should not be used for disposal of septic tank pumpings, raw sludge, or hazardous wastes unless special environmental protection measures are instituted. Runoff and leachate control facilities to prevent groundwater and surface water contamination should be incorporated at all landfills receiving liquid sewage sludge.

71. Various sludges generated from industrial processes and pollution control systems may be eventually utilized as fill or, in the immediate future, may be of concern due to disposal in landfills. Disposal of sulfur oxide sludges generated by flue-gas desulfurization systems is being investigated by numerous researchers (Phillips and Wells, 1974; Minnick, 1974).

Studies have also been conducted on disposal requirements for process-related solid wastes unique to the chemical industry (Saxton and Narkus-Kramer, 1975). Taconite tailings represent another industrial waste material potentially subject to Sec. 404 permit requirements (Weston and Woldman, 1971). Research has been conducted on the development of paper mill sludge landfills, primarily for the purpose of developing guidelines and recommendations for the design and operation of these facilities (Andersland et al., 1974).

72. Hazardous waste materials which are disposed of into chemical landfills may also be subject to Sec. 404 permit requirements. On-going research is addressing the disposal of hazardous residuals on land and is particularly oriented to leachate formation and control (Schomaker, 1976).

PART III: PHYSICAL, CHEMICAL, AND BIOLOGICAL IMPACTS

73. The environmental response to any fill discharge operation will be a complex synthesis of many factors. For purposes of discussion, it is necessary to sort these into manageable categories, recognizing that any sorting is somewhat arbitrary and that there will be gaps and overlaps. One choice would be to sort according to type of impact such as physical, chemical, and biological. Others would be according to type of fill material, or according to discharge operation (purpose). It seemed most useful to use a combination; accordingly, this part first presents overviews of general physical, chemical, and biological impacts. This is followed by a discussion of anticipated impacts according to type of fill material. This part concludes with an examination of evaluation techniques for fill materials.

Overview of Physical Impacts

74. Fill discharge activities which produce physical impacts encompass those engineering efforts which result in

(1) Creation of additional dry land or wet land.

(2) Changes in the landscape and topography of existing dry land or wet land.

(3) Changes in the bottom profile and bathymetry of inland and coastal water bodies.

75. Consequently, the physical impacts of fill discharge activities can be studied in terms of their direct (or primary) manifestations as well as their indirect, attendant, or secondary manifestations. Direct manifestations relate to the geohydrological and geophysical (erosion/deposition) changes that may be expected, and the changes in natural/man-made habitats. Secondary manifestations (to which greater significance is generally attached from the environmental viewpoint) appear as chemical or biological impacts.

76. A listing of some potential physical impacts of fill material discharge is in Table 3. The listing does not preclude the simultaneous occurrence of several physical impacts. For example, destruction of a natural wetland habitat by a highway fill may also cause changes in area

Table 3. Examples of physical impacts resulting from fill material discharge

Geohydrological	
	Change in infiltration
	Change in flow regimes
	Change in water levels
Geophysical	
	Change in erosion/deposition patterns
Land Usage	
	Destruction/alteration of natural or man-made habitats
	Creation of habitats

flow regimes and water levels. The chemical and biological implications of the changes in Table 3 will be discussed in subsequent sections of this part. For purposes of illustration, brief examples of two physical impacts (changes in infiltration and changes in erosion/deposition patterns) will be presented in this section.

Infiltration

77. When fill material is placed upon land, water can become impounded. If the soils are impermeable, ponding occurs as the result of severe storms, and stress loading by water can rapidly deform the fill. If allowed to continue, the water table may be depressed, resulting in an increased hydraulic gradient, diversion of groundwater flows, and alteration of the hydrologic cycle. (Wright and Rumer, 1975).

78. Part of the reduced infiltration may be caused by a slurry (formed when the fill mixes with water) which flows into and seals the soil to a depth, D, described as follows:

$$D = \frac{dp\ Z\ n\ \cos\Phi}{\tau\ 6(1-n)}$$

where dp = pressure differential

Z = mean particle diameter

τ = gel strength of slurry

Φ = angle of tortuosity

n = soil porosity

79. Such a process was reported by Nash (1974), in which Wyoming bentonite mud formed a suspension which deposited a stabilizing filter cake upon a soil surface. As water flowed through the filter cake (streaming potential), it suffered a loss in hydraulic head. In addition, the cake acted as a permeable membrane to separate anions from cations. For these reasons, an electrical potential difference was established between the mud and water which helped prevent the collapse of fill. Sediment or fine gravel (resulting from erosion) might also clog the natural passageways of soils and prevent recharge of the water table.

Erosion/deposition

80. Shoreline and coastal erosion and deposition patterns can be altered by fill projects. Jetties are often built to minimize deposition resulting from wind and tidal action. Unfortunately, this action occasionally complicates the hydrodynamic environment. Perhaps the most significant and destructive complications are illustrated along the Oregon coastline (Komar et al., 1976). Accretion and shoreline advancement has occurred between the

jetty and pre-jetty shorelines. This area fills with material until the new shoreline is straight and in equilibrium with incoming waves. At Tillamook Bay, the north shoreline began advancing seaward when the north jetty was completed in 1917. Simultaneously, erosion began to the south at Bayocean Spit. Similar events to those at Tillamook Bay occurred at the mouths of the Umpqua and Coquilla Rivers and at Yaquina Bay (Komar et al., 1976).

81. Given initial shoreline configuration and the offshore wave parameters of height, period, and approach angle, a simulation model verified that the material was eroded from one beach and transported to the jetty embayment (Komar et al., 1976). The shoreline was divided into a series of uniform cells, each with width dx and individual lengths y_i. The shoreline advance (or retreat) for a given cell is

$$y_i = \frac{\{S_{(i-1)} - S_i\}}{d} \frac{dt}{dx}$$

where S_i = littoral drift to cell i

d = deposited or eroded sand depth

dt = time increment (days)

Overview of Chemical Impacts

82. Strictly speaking, the chemical impacts of fill discharge will include

(1) Changes in the concentration of specific chemical species.

(2) Shifts in the rates and/or extents of chemical reactions.

(3) Changes in the parameters that control the rates and/or extent of chemical reactions, such as pH, pε (-log(e)), and temperature.

Chemical impacts are intimately associated with physical and biological phenomena, and in this part they are primarily addressed in terms of biological consequences.

83. While biological consequences are important, it is simplistic to limit the significance of chemical impacts in such a manner. Such a point of view can easily miss the basic cause or explanation of what might otherwise seem to be random and unrelated phenomena. Table 4 lists various components which should be examined in order to develop a complete understanding of the chemical impacts of fill material discharge. One possible

Table 4. Information needs for assessment of chemical impacts from fill material discharge

1. Techniques for chemical analysis of fill material.
2. Chemical characterization of fill material.
3. Chemical effects of fill discharge

as related to	considering	divided into
a. nature, amounts of fill material	a' effects during operation	a" primary effects
b. type of operation; e.g., purpose	b' short-term effects	b" secondary effects (i.e., causal relationships)
c. nature of primary and secondary receiving systems	c' long-term effects	c" ultimate effects
	d' relationship to physical effects	d" effects of long-term operations
	e' relationship to biological effects	

4. Mechanisms of chemical effects.
5. Methods for assessing, evaluating, and predicting chemical effects in general and/or specific cases.
6. Methods of minimizing chemical effects (e.g., site selection, operation, and treatment).

approach in attempting to gain an overall perspective on chemical impacts is to consider processes, control factors, and effects as shown in Table 5. Tables 4 and 5 are suggested as a possible framework for a comprehensive, critical discussion of the chemical impact of fill discharge operations. Unfortunately, the state of knowledge is such that the strict use of this framework is not practical at this time. A great amount of synthesis and evaluation of widely scattered information still needs to be accomplished.

Overview of Biological Impacts

84. In studying the biological effects of the discharge of fill material, the ideal approach would be to examine an ecosystem (the interaction of the organisms with the chemical and physical environment in a given area) as a total unit rather than looking at the effect of a particular action or pollutant (defined by Menzel, 1973, as a change in the environment which makes it unsuitable for the well-being of the organisms or organisms of concern) on a particular organism. This is because organisms not only interact with the chemical and physical aspects of the environment, but they also interact with other organisms; thus, the effect that a pollutant such as a metal has on an organism will result in additional effects on other organisms in that ecosystem and, at times, even outside of that ecosystem.

85. Wetlands represent one of the most important types of ecosystems for fill discharge operations. Of concern is the fact that there are many types of wetlands. Marcellus (1972) divided Virginia wetlands into marshes, swamps, wetland woods, tidal flats, open creeks, sand beaches, ponds, temporary lakes, and dredged wetlands. Cowardin et al. (1976) classified the wetlands of the United States into vegetated wetlands and aquatic habitats (including forested, shrub, emergent, and moss/lichen wetlands; floating-leaved beds; and submergent beds) and nonvegetated wetlands and aquatic habitats (including rocky shores, beaches and bars, flats, reefs, bottoms, riffles, and pools). A freshwater wetlands inventory procedure was published by the U.S. Army Engineer District, Memphis (1976), and wetlands are identified by vegetative lists. Shaw and Fredine (1971) classified the wetlands of the United States into twenty types grouped under four categories: inland fresh areas, inland saline areas, coastal fresh areas, and coastal saline areas.

Table 5. Chemical impact relationships

PROCESSES

Fill Material	Interface	Interstitial	Bulk Water
	Dissolution / Precipitation		Redox
			Acid/base reactions
		Diffusion	Complex formation
	Sorption / Desorption		Uptake
	Ion exchange		Excretion

CONTROL FACTORS

Fill Material	Interface / Interstitial	Bulk Water
Nature of surface	Permeability	Redox potential
Surface area	Viscosity	pH
Condition of surface	Mixing	Ligand concentrations
Time	Temperature	Cation concentrations
	Time	Anion concentrations
		Mixing
		Transport
		Light
		Temperature
		Time

EFFECTS

Primary

Changes in concentration of various chemical species in receiving ecosystem

Secondary

a) Shifts in control variables; e.g., pH, pε, pM pL, DO
b) Shifts in rate and extent of chemical reactions
c) Changes in nutrient levels and rates of nutrient availability
d) Changes in levels of toxic materials, inhibitors, stimulants

Tertiary

a) Changes in biological community
b) Changes in chemical quality
c) Changes in physical quality

86. In addition to the types of ecosystems and their importance to man, an understanding of several ecological concepts is necessary in order to evaluate the effects the discharge of fill material will have on the biological environment. These concepts include the flow of energy and its relation to the productivity of ecosystems, storage capacity of ecosystems, the food relationships within ecosystems (food webs), and succession in an ecosystem from one type of species to another type. The additional concepts of ecotones, diversity of an ecosystem, carrying capacity, and indicator species are also useful. A definitive presentation of these concepts is given by Odum (1971), Warren (1971), Christman et al. (1973), and Clark (1974).

87. The biological impacts of fill material discharge can be presented in terms of precursor physical and chemical changes. This section will summarize the biological consequences of certain land-use changes (destruction/alteration or creation of habitats) and geohydrological changes (water flow and level). The biological changes resulting from chemical impacts will be summarized according to anticipated changes in water-quality parameters (for example, solids, organics, nutrients, pesticides, and other toxic substances). Since the primary results of geophysical changes are erosion and increased solids in water, this category of physical impacts will be addressed in the chemical impacts sub-section.

Destruction/alteration of habitats

88. Dams and levees. Many acres of habitat are covered and/or flooded by dam and levee construction, although a more significant impact probably lies in the fact that these projects often make it possible for large-scale development of areas formerly left as wetlands and floodplains. Floodplain and coastal zone usage for urban, industrial, and agricultural purposes increases when flooding protection is improved from upstream dams and levees (Ketchum, 1972).

89. According to Darnell (1976) and Gunter (1957), levees are primarily responsible for the disappearance of the Mississippi River floodplain habitat which was once a haven for millions of water birds and other aquatic animals.

90. Dams and levees can also act as physical barriers to anadromous fish migrations and other aquatic animals. For example, the first levee constructed on the Mississippi River was a three-foot high barrier built around New Orleans in 1717 (Gunter, 1956). Since that time, several thousand miles

of levees have been constructed along the Mississippi River and other floodways. Most of these more recent levees are several times higher than those first placed around New Orleans, and the effect has been to cut off aquatic animals in the main water body from the swamps and floodplains. Since many of these organisms prefer the quiet backwaters over the swift and turbid main stream for spawning purposes, the biological consequences may be significant (Gunter, 1956). Unfortunately, very little quantitative research has been attempted on the effects of the construction of levees on aquatic population changes.

91. Numerous references contain extensive discussions of other physical and chemical impacts of dams and levees (Sylvester, 1958; Copeland, 1966, 1970; Wirth et al., 1970; Funk and Ruhr, 1971; Turner, 1971; Bayly and Williams, 1973). Extensive review of this literature is considered beyond the scope of this study.

92. Channelization. Channelization is not normally considered as a fill discharge project, although land development can occur on the materials removed from streams. In addition, land development projects may involve the creation of new canals or improvement in existing canals/channels. To illustrate the environmental impacts from fill material generation, several studies will be mentioned (Darnell, 1976; Burnside, 1976; Beland, 1953; and Kaplan et al., 1974).

93. Darnell (1976), reporting on work by others, stated that channelization reduces the size and diversity of stream habitats, destroys key productive areas, and causes shifts in species composition. In all cases unmodified stream sections were many times more productive than the channelized streams.

94. Burnside (1976) reported on the effects of channelization on fish populations in the Boeuf River in northeast Louisiana. A taxonomic survey indicated that dredging of the Bouef River produced harmful effects on the dispersal of some species of fish but did not effect others. Those species which are less tolerant of destruction of natural habitat showed a decrease in abundance in the dredged areas.

95. In another channelization study, Beland (1953) concluded that channelization decreased the value of the Colorado River as a habitat for game fishes by (1) draining the adjoining backwater lakes and sloughs,

(2) eliminating riparian vegetation cover, (3) eliminating the eddies and holes along the river littoral zone, (4) increasing water turbidity, (5) increasing bank erosion, and (6) reducing the amount of spawning area.

96. Kaplan et al. (1974) studied the populations of epi- and in-fauna from 10 months prior to 11 months after a navigation channel was dredged through Goose Creek in Long Island, New York. Significant reductions in standing crop figures and species and specimen numbers occurred in both bay and channel waters. *Mercenaria mercenaria* populations were reduced, but without evidence of mass mortality. Biomass recovery in the channel was affected by sediment composition, but seasonal and sediment type variations were not significant in the bay as a whole.

97. The effects of dredging, filling, and canalizing in the coastal shallow waters and wetlands of South Florida has been presented by the South Florida Environmental Project (U.S. Department of Interior, 1974). Canals and associated fills have a detrimental effect on fish and wildlife habitat by direct destruction of wetlands, degradation of water quality, and habitat oversimplification. Problems in the disposal of spoil materials from maintenance dredging operations of existing residential canal systems are also identified. As wetlands are filled and destroyed to create residential real estate, the water purification or nutrient scrubbing function of wetlands is lost while a new system is created that will generate an increased load of nutrients and other pollutants into estuarine waters. Designing canals to take as full advantage as possible of tidal water exchange and the installation of rock or rubble riprap instead of vertical bulkheads was recommended. to provide a near-natural surface for marine animals and plants to colonize.

98. Highways. Highway construction through wetland areas can result in large losses of habitat. In addition to the marsh loss from the highway itself, diked disposal areas involve permanent loss of approximately 2.4 acres of marsh per 100 feet of Interstate highway (Gosselink et al., 1973). Although conventional undiked disposal requires less area, this results in a great deal of fine sediment being carried into adjacent waterways. Another biological impact results from the physical barrier effect. For example, streamside highways may prevent access to the water so that many animals may not be able to drink or search for food. Construction may block along-stream passage of some species, and roadside kills may be excessive.

99. Small structures and related activities. A recent study of the potential environmental consequences of small structures and related activities in coastal bodies of water (Carstea et al., 1975) provides specific impact analyses, with examples, for riprap, bulkheads, groins, jetties, mooring piles, piers, dolphins, ramps, outfalls, submerged lines and pipes, and aerial crossings. The study summarizes potential ecosystem impacts resulting from these structures and activities into four biological areas including impacts on low marsh organisms, impacts on high marsh organisms, impacts on aquatic biota, and impacts on benthic organisms. The major impacts will result from productivity and nutrient cycling losses; increases in runoff, turbidity, and sedimentation; introductions of toxic elements (heavy metals) and petroleum by-products; and animal behavioral modifications. Bulkheads and other deep-water structures may cause permanent elimination of valuable intertidal and subtidal wateredge habitat (Sykes, 1971).

100. Trent et al. (1972) conducted studies during 1969 to compare the ecology of a natural estuarine area (marsh and bay) with the ecology of an adjacent estuarine area altered by channelization, bulkheading, and filling. In each area, hydrographic factors, fishes, crustaceans, and benthic macroinvertebrates were sampled. The growth and mortality rates of juvenile oysters were measured. In general, productivity was highest in the marsh, intermediate in the canals of the altered areas, and lowest in the open bay. Corliss and Trent (1971) compared phytoplankton production between an undredged marsh area, a bay area, and an adjacent marsh area altered by channelization, bulkheading, and filling. Average grass production (milligrams of carbon per litre per day) in the altered area (canals) was 8% higher than in the marsh and 48% higher than in the bay during summer. Gross and net production were significantly higher in the canals and marsh than in the bay; differences between the canals and marsh were not significant.

101. Beach fill. Thompson (1973), in his investigation of over 1500 references, found little research specifically concerning the placement of dredged beach fill. He noted, however, that beaches are a harsh environment where the flora and fauna are often limited in number and species. From this observation and the observation that beach animals are adaptive and soon repopulate a disturbed beach, Thompson concluded that little lasting harm is apparent from the placement of beach fill. Darnell (1976), while agreeing

that many beach species are capable of repopulation rather quickly, noted that frequent beach maintenance is often required. Since the beach construction generally works against natural erosion forces, repeated habitat destruction is often necessary to maintain artificial shoreline stability.

102. Offshore projects. Rounsefell (1972) conducted an evaluation of the ecological effects likely to ensue from alteration of existing habitats through engineering activities in the offshore marine environment. In general, evaluation of current knowledge of the probable ecological effects of various types of offshore construction reveals only minimal danger from the majority of construction programs. Construction of artificial islands has the greatest potential environmental effect. One of the beneficial features of the Rounsefell report (1972) is the presentation of a reference index organized by project type and construction effects.

Creation of habitats

103. Certain fill projects may lead to the creation of new habitat areas or improvements in existing ones through modification. For example, Ketchum (1972) cites studies indicating that jetties may act as a base for many sessile organisms as well as a habitat for sport fish. Work by Ortolano (1973) dealing with impoundments indicated that new reservoirs attract many water birds, wildfowl, and possibly other animals not commonly observed in the preimpoundment area. Artificially created or enhanced beaches may also provide habitat and are usually repopulated rapidly (Thompson, 1973).

104. Fastlands created as a result of dredged material disposal also provide new habitat areas. Habitat can be potentially improved by marsh creation and enhancement, planned development and colonization of dredged material islands for terrestrial wildlife, and selective dredged material disposal to enhance bottom substrate for the improvement of sport and commercial fishing (Ketchum, 1972). Revegetation of dredged material disposal areas in saline sites appears to be a problem, especially for diked disposal areas (Gosselink, 1973). Although revegetation in salt marshes is slow and disposal areas may never return to marsh conditions, revegetation of freshwater sites may be quite rapid and often with a very diverse flora.

105. Ortolano (1973) has noted that new bird nesting areas and/or tidal marshes may be created by the planned use of dredged material. Boyd et al. (1972) reported that wildlife and fishery biologists have been using artificial

environmental settings as habitat for waterfowl, deer, and many endangered species for some time. Impoundments can be formed on dredged material islands and such impoundments have been proven highly productive in shrimp, oysters, and other commercial species.

Flow regime and water-level modification

106. Alterations in both natural flow patterns and water levels can occur as a result of projects involving fill material discharge. Stream velocities and discharges can be increased or decreased, discharges can be changed from continuous to intermittent to nil, and water levels can be increased or decreased.

107. Darnell (1976) quoted several researchers showing that high stream velocities generally have adverse affects on the stream biota. Reported effects of high velocities include elimination of young trout and reductions in density of older fish; damages to invertebrate populations; decreases in food supplies; changes in species composition; decimation of developing eggs and young through erosion of, or siltation in, spawning areas; and flushing of organic matter. Low velocities can be even more devastating to aquatic life than high velocities. Reported effects of low velocities include reduced oxygen levels and increased carbon dioxide levels; trout movement to deeper pools of water; and reductions in the number of trout and salmon that hatch, and the size and viability of those that do hatch.

108. Six basic problems resulting from reduced freshwater inflow into coastal areas are (1) long-range reductions in estuarine fertility; (2) severe damages to the production of valuable oysters, shrimp, fur animals, and waterfowl; (3) interferences with larval migrations; (4) elevations of salinity and resultant penetration by marine competitors, diseases, parasites, and predators; (5) reductions in chemicals which help young marine animals find their ways into the estuary; and (6) decreases in the annual fish and shellfish harvest (Darnell, 1976). Decreases in discharge may also cause decreases in sediment transport. On a subsiding coast, elimination of the normal freshwater sediment input upsets the land-water equilibrium and subsiding marshes tend to become open-water areas. When this happens, production is reduced and the area becomes a nutrient sink. Birds and mammals can no longer find food and refuge there. Shifts in vegetation are accompanied by increased salinity and subsidence. Aquatic animals are adversely affected by the habitat loss, decreased food supply, increased salinity, and, possibly, increased hydrogen

sulfide. Gunter et al. (1973) conducted a detailed study of the influence of salinity changes on animals living in coastal waters.

109. Intermittent flows may reduce a stream environment to a series of stagnant pools, thus causing disruption and/or death to those aquatic species requiring flowing water habitats. In addition, intermittent flows expose the surviving fishes and invertebrates to greater predation by both aquatic and terrestrial animals.

110. Stream discharges can be completely eliminated through physical barriers and resultant diversions created by fill material projects. For example, Darnell (1976) found that a levee placed across the upper end of a coastal marsh will cut off all distributaries feeding the marsh, prevent freshwater flushing, prevent annual renewal of sediments and nutrients, and end the formation of new marshes.

111. Variations in stream velocities and discharges can lead to changes in local water levels. Hagan and Roberts (1972) noted that in reservoirs with greatly fluctuating water levels, vegetation is killed along the edges by a high water level and unsightly conditions are exposed when the water level is drawn down. For example, prior to the construction of Shasta Dam, low flows in the Sacramento River during the summer months allowed the river banks to drain. Grass, weeds, and willows grew on the steep banks and stabilized them. Since Shasta Reservoir began operations, summer flow water levels are within a few feet of natural ground elevation. The banks never dry out and have suffered considerable damage from cave-ins and erosion.

112. Hagan and Roberts (1972) also identified downstream hydrograph modifications as a result of dam construction. Townsend (1975) reported on possible downstream effects of Bennett Dam on the Peace-Athabasca Delta and Lake Athabasca in British Columbia, Canada. During the summer of 1968, following closure of the Bennett Dam the previous winter, water levels in Lake Athabasca failed to rise as high as usual and, in fact, peaked almost 5 feet below levels that had been established in the preceding 10 years. Low water levels on the Delta and in the Lake also persisted during 1969 and 1970. The lower water levels exposed thousands of acres of marsh and lake bottom, thus advancing plant succession (toward the less desirable willow communities), threatening access of migrating fish to the Delta's spawning lakes, and reducing nesting habitats for waterfowl and overwinter habitats for muskrats. The resultant drastic decline in the muskrat population affected the local economy due to dependency on trapping.

113. The long-term effects of the changed regime resulting from Bennett Dam were predicted to decrease the important shoreline of perched basins by approximately 50%; to cause plant succession to proceed uninterrupted for longer periods of time, thereby accelerating the aging of the delta; to shift plant zones to lower elevations around lake margins; and to reduce the vertical ranges and area of early successional plant communities by as much as 50% (Townsend, 1975). Waterfowl production is expected to decline by 20-25%, and muskrat populations will decrease by 40-65%. Bison grazing meadows will suffer losses although moose habitat is expected to improve. The decrease in water levels will increase the risk of a delay in walleye spawning runs to the Delta lakes.

Biological effects of chemical pollutants

114. Chemical impacts from the discharge of fill material will result from either the release or sorption of chemicals or solids or from other chemical changes. The release or sorption of chemicals or solids (including suspended solids, organics, nutrients, and toxic substances) to or from adjacent waters and the fill site may then result in changes in pH and concentrations of dissolved gases such as carbon dioxide and oxygen.

115. The effects of released pollutants on the biota of navigable waters are very complex and diverse. They range from no measurable effect to acute toxicity. Other effects on biota include stimulation, inhibition, and bioaccumulation. Chemical substances may interact and cause synergistic or antagonistic biological effects. Many synthetic organic compounds and several heavy metals are persistent in the environment and continue to be toxic in aquatic systems for years. In addition, normal changes in pH, redox potential, temperature, and dissolved oxygen concentration may result in changes in the solubility and sorption of chemicals in water and sediment, thus changing the effects those chemicals have on organisms.

116. In order to summarize the variety of biological changes resulting from released pollutants and or chemical changes, specific information is organized by type of pollutant/change.

117. Turbidity, suspended solids, and sediment. The exact values for turbidity, suspended solids, and sediment which cause adverse effects on aquatic organisms are not known (Everhart and Duchrow, 1970). Differences in background levels and in sediment composition, size, and shape make universal statements concerning biological effects difficult, if not impossible. The problem is further complicated by the lack of consistent definitions for the

terms turbidity and suspended solids, as well as the variety of methods and equipment utilized in their measurement. It can be shown, however, that turbidity, suspended solids, and sediment can and do exert considerable biological stress under certain conditions.

118. All streams contain suspended material which can produce turbidity. Native aquatic flora and fauna are generally well adapted to normal fluctuations in these natural conditions. Most of these organisms can also withstand gradual increases in suspended solids (Everhart and Duchrow, 1970). However, large changes (especailly sudden increases) can alter the character of entire lotic populations. Some commonly cited effects of high suspended solids concentration are reduced photosynthesis, smothering of benthic organisms, destruction of habitat, inhibited feeding activity, fish mortality, loss of fish production, species simplification, and reduction in biomass. Suspended solids are also capable of raising water temperatures by absorbing radiant energy and as water temperatures increase the dissolved oxygen concentrations will be reduced (Darnell, 1976).

119. In studying the effects of dredging, Sherk (1971) conceptualized that each site has unique and inherent physical, chemical, and biological limits beyond which significant effects will occur and that suspended and deposited sediment affects living systems in a variety of ways. Chronic exposures may affect any life history stage and may eliminate certain species through reductions in reproductive success. Sherk et al. (1972) later suggested that organisms may not respond to suspended solids concentrations in general but to the number of particles in suspension, their densities, size distribution, shape, mineralogy, presence of organic matter and its form, metallic oxide coatings, and sorptive properties. He concluded that each project should consider the effects of suspended solids by determining the type of particles to be suspended, their transport, and the substratum changes produced; the biological activity of the water column and sediment-water interface; the introduction to the water column of particles with associated chemical or biological components; and the relationship between the properties of the suspended matter and the species of the project area, their requirements, and repopulation dynamics. While these considerations were directed to dredging operations, they would also apply in general to most filling operations.

120. Reviews of the literature on the effects of suspended solids on aquatic species have been presented by several authors including Cordone and Kelly (1961), Wilber (1971), Sherk and others (1971 and 1972), and Peddicord et al. (1975).

In order to summarize the general biological effects of turbidity, suspended solids, and sediments, the following sub-sections are included: effects on plankton, effects on benthos, and effects on fish.

121. (a) Effects on plankton. High levels of turbidity can cause severe reductions in phytoplankton populations, primarily by the reduction of light necessary for normal photosynthetic activities. The link between high turbidity and reduced primary production has been demonstrated repeatedly (Langlios, 1954; Verduin, 1954; Wickett, 1959; Flemer et al., 1967; Sherk and O'Connor, 1975; and Samsel, 1973). Settleable solids have been shown to be the most important element limiting light transmission in all but the lowest turbidimetric measurements (Everhart and Duchrow, 1970); however, the extent to which a specific concentration contributes to light reduction is impossible to quantify. Variables such as size, shape, specific gravity, and refractive properties of the solids make nearly every situation unique.

122. Additional destruction of algae may be caused by flocculation and precipitation with silt particles. This effect was also noted by Lackey (1959), who demonstrated that clay was capable of removing in excess of 99% of the algae present.

123. The primary direct effect of suspended solids on zooplankton appears to be feeding interference. Sherk and O'Connor (1975) have shown that suspended solids levels comparable to those encountered during storms and dredged material disposal activities can reduce food cell ingestion of zooplankton more than 50%. From their studies on phytoplankton and zooplankton, Sherk and O'Connor (1975) surmised that frequently encountered levels of suspended solids could dramatically effect the food chain. They concluded that uncommon levels of suspended solids could cause reductions in energy flow and greatly limit the food supply of many important estuarine vertebrates and invertebrates.

124. (b) Effects on benthos. In a literature review by Hollis et al. (1964), 27 papers were cited concerning the adverse effects of suspended solids and siltation on benthic organisms. Unstable and shifting bottom conditions was identified as the major impediment to benthic animals. Taylor and Saloman (1969) and Smith and Moyle (1944) also concluded that soft and shifting sediments can be the principal limiting factor on benthic abundance and diversity. Since the flora and fauna on shifting beds are generally sparse and highly mobile, these communities are usually of less commercial importance than those found on more stable bottoms (Thompson, 1973). Sykes and Hall (1970)

suggested that the limiting nature of soft sediment is primarily due to physical smothering and oxygen starvation caused by the generally high organic content of soft sediments. Additional loss of bottom dwellers may be attributed to scouring caused by high flow rates (Darnell, 1976).

125. Sediment loads and siltation can have dramatic and far-reaching impacts on benthic species. Ellis (1931) indicated that many upper Mississippi River species were becoming extinct or greatly reduced in numbers due to bottom siltation. Studies indicating significant reductions in entire benthic populations several miles from silt pollution sources have been reported by Wagner (1959). Casey (1959) found a total lack of bottom animals 1/4 mile from a stream dredging operation. Other studies have shown benthic losses to exceed 50% even at considerable distances from sediment sources (Sumner and Smith, 1940; and Cronin, 1971). Such decimations of benthic populations will obviously affect the food chain. One study, for example, has shown that when certain bottom-dwelling food sources are eliminated, some fish will starve (Hollis et al., 1964).

126. Sediment loads may have adverse effects on commercially significant bottom-inhabiting species such as shellfish. Loosanoff (1961) stated that dead and dying oysters always contained large amounts of silt in their gills when found in turbid waters. He concluded that long exposures to suspended materials (48 hours) might have injured the delicate ciliary mechanisms of the gills and palps. Heavy winter oyster kills during turbid water conditions led Korringa (1952) to conclude that the oysters died after being weakened by the cold and becoming unable to expel adequate amounts of sediments from their gills.

127. Mackin (1961) conducted a field study of the effect of turbidity from small pipeline dredges on oysters. He found that particles were not transported more than 1300 feet and that turbidities did not exceed normal maxima beyond a few hundred feet from the discharge point. There was little effect on the oysters by particulate matter, and it was determined that oxygen sags of significant magnitude were unlikely.

128. Davis and Hidu (1969) conducted a laboratory study of the effects of silt and kaolin on eggs and larvae of oysters and clams. They found that oyster eggs were primarily affected by the relatively large silt particles, while clam eggs were affected most by the small kaolin particles. Growth of oyster larvae was signficantly reduced by silt as low as 190 mg/l; higher

concentrations produced greater effects, including the death of all larvae at 3000 mg/l. Davis (1960) also found that increasing concentrations of silt and kaolin increased the mortality of the eggs and larvae of the hard clam. Larvae were most affected by ingested particles that mechanically blocked the digestive tract.

129. Pratt and Campbell (1956) studied the hard clam and found that greater intake of fine particles resuspended from bottom muds required more frequent cleaning of the filtering apparatus which increases energy requirements, reduces active feeding time, and wastes food due to incomplete sorting. These factors were suggested as the causes for the observation that clams in mud bottoms in the field showed slower growth than clams in sandy bottoms. Peddicord (1973) made a similar observation with the brackish water clam.

130. Increased concentrations of suspended solids were found by Johnson (1971) to reduce the growth rate of the slipper limpet. This observation was made both in the field and in the laboratory, and Johnson concluded that the increased concentrations interfered with normal feeding and required an energy expenditure for additional pseudofeces production, thereby accounting for the reduced growth rate found in turbid waters.

131. The effect of silt on 18 species of bivalves was studied by Ellis (1936), and he found that most died when permanently covered with 1/4 to 1 inch of deposited sediment. Chiba and Ohshima (1957) investigated the effects of suspended bentonite on four bivalves and found that concentrations of 1000 mg/l did not reduce the pumping rate in any of the species tested. Peddicord et al. (1975) found that smaller mussels were killed by much lower concentrations of suspended bentonite than were larger mussels. Summer temperatures exaggerated the lethal effects of suspended bentonite concentrations on mussels, while lower dissolved oxygen concentrations showed a similar correlation but to a lesser degree.

132. The filtering rate of the scallop and the mahogany quahog exposed to suspended kaolin was shown by Stone, Palmer and Chen (1974) to be reduced. While no structural gill damage was found, there was an increase in mucous-secreting cells on the gill filaments, thus requiring more energy to clean.

133. Reeve (1963) studied the effects of mixed suspensions of food cells and soil particles on adult brine shrimp and found no selection between these two types of particles; further, maximum filtration rate was independent of the nature of the particles. Another study on crustaceans (nauplii, copepodids, and adults on a marine copepod, *Calanus helgolandicus*)

was performed by Paffenhofer (1972). In mixtures of algal cells and 10 mg/l red mud, growth was delayed, especially of older animals. The reproductivity of female adults appeared to be inhibited by the red mud because no ovarian development was found. The movement of all adults was more sluggish in the mud than in the controls. The sand shrimp was found to have a high rate of survival under conditions of low temperature and saturated dissolved oxygen, even in high concentrations of suspended bentonite; however, survival was reduced by a decrease in dissolved oxygen from saturation to 5 mg/l and by an increase to summer level temperatures, even at saturated oxygen levels (Peddicord et al., 1975).

134. Not all benthic organisms are equally affected by sediment loads and siltation. Many animals adapt by burrowing, closing valves, avoidance, or developing a tolerance to the sediment stress. If bottom conditions have not been altered too drastically, repopulation will frequently occur after a period of time. A study made on the Thames River in Connecticut showed significant faunal repopulation at the disposal site a year after dredging activities ceased (National Marine Fisheries Service, 1976). This finding, as well as the continued presence of Teptocheriur and Ampelisca, which are typical of the natural sediments of the area, contributed to the study conclusion that the overall benthic productivity suffered little.

135. (c) Effects on fish. Of all the organisms affected by turbidity, suspended solids and sediment, fish are perhaps the most studied. A host of reports demonstrating adverse effects on coldwater and game species have been published. Species with low tolerances for environmental change are the most affected, with greatly reduced populations or local species elimination a possibility (Hollis et al., 1964).

136. Everhart and Duchrow (1970), Sherk et al. (1974), and Sherk and O'Connor (1975) attribute fish mortality to the coating effect of fine particles settling on gill filaments. This results in decreased respiration and waste exchange, with eventual death by asphyxiation. Injured or impaired gills would first affect those species with the highest oxygen requirements. Other species with lower oxygen needs would succumb to only high concentrations of suspended solids, if at all (Sherk and O'Connor, 1975; and Sherk et al., 1974).

137. In addition to possible death, heavy sediment loads may affect fish by reducing necessary feeding visibility and causing physical abrasions which can increase susceptibility to parasites and disease (Everhart and

Duchrow, 1970). Other sublethal effects identified by Sherk and O'Connor (1975) are hematological compensation for reduced gill capacity, gut packing with ingested solids, gill tissue disruption, increased activity, and reduced energy reserves.

138. Spawning grounds themselves may be greatly reduced or eliminated as a result of turbid waters and siltation. Six separate studies were reported by Hollis et al. (1964) indicating destruction of spawning grounds by siltation. Reports by Cooper (1956) and Smith (1940) demonstrated that spawning salmon will avoid turbid water and crowd into clear-water areas to such an extent that they destroy spawning areas. In an estuarine study, Mansuetti (1961) showed that siltation in a number of water bodies had caused large losses and displacement of normal spawning grounds.

139. Gammon (1970) found losses in fish populations of approximately 60% when inert quarry suspended solids levels increased to more than 80 mg/l over background levels. When lesser concentrations of between 20 to 40 mg/l were experienced, the populations still exhibited reductions of about 25%. For normal fluctuations the fish populations were able to recover relatively quickly. In 1969, however, a suspended solids level estimated at 150 mg/l greatly reduced the total fish density. Two years after this episode the fish population had failed to recover despite reduced suspended solids input.

140. Game and commercially important fish species are generally the most sensitive to turbidity and siltation. They are frequently driven away by gill irritation, inability to locate forage fish, and the destruction of aquatic vegetation necessary for cover and spawning purposes (Hollis et al., 1964). Findings by Trautman (1957) indicate that siltation can cause a shift from large important food-source species to smaller non-food varieties. Trautman also attributed the reduction of Ohio Lake game fish to increased siltation, finding support from Langlios (1941), who made similar observations in his studies on Lake Erie. Heimstra, Damrot, and Benson (1969) found no short-term adverse effects to small largemouth bass and green sunfish exposed to natural levels of river bottom silt, but noted reduced general activity in the bass after 30 days. Both species "coughed" more frequently in more turbid water, and this was interpreted as an effort to free the gill lamellae of accumulated particles. Peddicord et al. (1975) found that fingerling striped bass (*Morone saxatilis*) were particularly sensitive to suspended bentonite concentrations. They found survival to decrease with increasing suspended bentonite

concentration, and as dissolved oxygen and temperature were reduced so was survival of the fingerlings.

141. One of the earlier and most widely quoted studies of the effects of suspended solids on freshwater fish was by Wallen (1951). He concluded that the direct effects of montmorillonite clay were not lethal to juvenile and adult freshwater fish at the concentrations found in nature. According to Hollis et al. (1964) and Everhart and Duchrow (1970), fish in their early developmental stages are the most susceptible to excessive suspended solids concentrations.

142. Shapovalov and Berrian (1940), Shaw and Maga (1943), and Wickett (1959) have, in separate studies, all reported large reductions in trout and salmon egg survival when subjected to above normal turbidities. The probable cause for fish egg mortalities is suffocation. Wilson (1960) blamed fish egg destruction on reduced oxygen supplies to the eggs due to diminished water seepage, and the physical coating of the eggs with an oxygen-impervious layer of silt. An experimental study on trout ova by Stuart (1953) led to similar conclusions.

143. In studies on cold-water fish, Hollis et al. (1964) reported gill inflammation to be fatal to trout at the rather low suspended solids level of 90 mg/l. Wagner (1959) found trout food and cover elimination in the Wynooche River, Washington, at slightly higher concentrations. A study on a Prince Edward Island trout stream was conducted by Saunders and Smith (1965). They reported a 70% trout reduction after the silting over of previously investigated stream sections. Herbert and Merkins (1961) exposed rainbow trout to about 270 mg/l of suspended kaolin and diatomaceous earth, and found 50% mortality after 185 days for both materials. At low concentrations of diatomaceous earth for 185 days, cases of thickened gill epithelial cells and frequent fusing of lamellal tips occurred, with the onset of such conditions ranging from as early as 11 weeks to greater than 8 months among individual fish. At the same concentration as used by Herbert and Merkins (1961) of 270 mg/l diatomaceous earth, Southgate (1960) found a median survival time for rainbow trout of only 11 days.

144. Everhart and Duchrow (1970) pointed out a number of studies which showed not only reductions in cold-water fish populations, but also shifts from cold- to warm-water species. These changes were attributed to increased turbidities from mining and logging practices.

145. Irwin (1960) reported that increasing turbidity and siltation in new reservoirs caused reductions in the reproduction of bass, shad, and flathead catfish. The fish larvae which were produced were limited due to lack of zooplankton.

146. Schubel and Wang (1973) found that hatching of white perch and striped bass eggs was significantly retarded by suspended solids levels of 100 mg/l and 500 mg/l, but the hatching success was not greatly affected. Different results were found by Morgan, Rasin, and Noe (1973) in studying the eggs and larvae of white perch and striped bass from upper Chesapeake Bay. The development rate of white perch eggs and larvae was slowed only about 1500 mg/l, and hatching success was not affected. Hatching was delayed up to one day by concentrations above 4000 mg/l. The hatching success of striped bass eggs was affected above 3400 mg/l, and the development rate was reduced by concentrations greater than 1500 mg/l. Peddicord et al. (1975) also found that 6-8 cm shiner perch were particularly sensitive to suspended bentonite.

147. Fish from San Francisco Bay were subjected to Bay sediment levels of 500, 1500, and 2500 Jackson Turbidity Units (JTU) for 42 days (U.S. Department of Interior, 1970). Turbidities above 500 JTU were found to significantly affect viability and cause weight loss, although there were large differences in absolute tolerance among various species.

148. In a study of coastal and estuarine fish life, Sherk and O'Connor (1975) reported the effects of suspended concentrations of Fuller's earth on 14 different species. Examination of the fish subjected to lethal concentrations showed that the gills and secondary lamellae acted as a filter, trapping particles on their surface. Since gill size increases with the size of the fish, the researchers were led to the conclusion that large fish would trap less sediment on their gills than smaller fish and thus be less affected. This could account for the fact that smaller and young fish tend to be the most sensitive to suspended solids. While examining the fish used in their experiment, they also found large quantities of ingested solids. They concluded that this was mainly the result of mucus cleaning of the gill surface.

149. In another study O'Connor, Neuman, and Sherk (1970) reported on the lethal effects of suspended solids on estuarine fish. While they found concentrations of suspended sediments that occur in estuarine systems during natural events such as storms and flooding, as well as during dredging and dredged material disposal, are within the range of lethal concentrations of Fuller's earth determined experimentally, they noted that most fish are capable of moving away from such a hostile environment. Characteristics of suspended solids that influence their affect on fish include concentration, particle-size distribution, angularity, sorbed toxic metals, organic content, and nutrient content. The most lethal effects of suspended mineral solids were found in fish in the lower trophic levels (anchovies, Atlantic silversides, and juvenile white perch), juvenile fish, and species with high oxygen requirements. Those species of fish that require very low levels of oxygen only succumb to high concentrations of suspended solids, but to widely varying degrees. Benthic species were least affected by high concentrations of suspended solids.

150. Rogers (1969) exposed several marine fish species to a variety of suspended particles, including diatomaceous earth, kaolin, incinerator fly ash, ground rock flour, powdered charcoal, pulverized glass, and glass beads, for 24 hours. Mortality for all species was found to increase with exposure time, temperature, increasing particle size, and increasing angularity. Since aeration of the water increased survival it was concluded that the fish were suffering from oxygen deficiency and that suspended solids affect fish by coating and clogging gills and/or through abrasion of the bronchial epithelium.

151. Organic materials. As organic matter enters an aquatic environment it exerts an oxygen demand which may reduce oxygen levels in these waterbodies upon biodegradation. The change in oxygen content of a small stream results in changes in the biological community or organisms in that stream. Some organisms can tolerate very low levels of oxygen (such as rough fish, some insects, worms, and air-breathing snails), while other organisms such as trout and most other game fish need fairly high concentrations of oxygen. Also, aquatic insects that serve as fish food need high oxygen concentrations. Therefore, as an oxygen-consuming waste is added to a stream and the oxygen content drops, there will be a change in the types of organisms or species to those that can tolerate low oxygen levels, with those types generally reaching fairly large population densities (Christman et al., 1973).

152. Most fish species require at least 5 mg/l of dissolved oxygen in order to survive and grow. Trout need at least 7 mg/l of oxygen. Fish do not require any single level of oxygen all the time. If a particular fish is growing, reproducing, or very active, it may require as much as 8 or 9 mg/l oxygen; while it is not involved in any of these activities, it may require only 2 to 3 mg/l (Christman et al., 1973).

153. A certain amount of organic enrichment can be desirable or beneficial if it leads to the production of game fish but does not reduce the oxygen content to a level where it eliminates certain species. Bacterial slime growths may develop in areas of high organic content, thus smothering incubating fish eggs and many aquatic insects. This bacterial slime growth can supply a food source for those insects that are not eliminated, and, if oxygen reduction is not critical, then fish species as sensitive as trout can take advantage of the increased food supply from the bacterial slime growth and show extremely high growth rates. In this case, organic enrichment may not necessarily affect ecosystem functions adversely (Christman et al., 1973).

154. Nutrients. Nutrient enrichment, such as the addition of nitrogen or phosphorus, primarily stimulates plant growth which may take the form of phytoplankton attached algae, rooted vegetation, or floating plants. This in turn stimulates animal production, decomposition, and increased oxygen demand. These effects (the increased production, increased decomposition, and increased oxygen demand) may exceed the rate of oxygen availability. This would lead to very low oxygen levels or total depletion, and, as mentioned earlier, most animals useful to man require minimum oxygen concentrations for respiration and growth. Again, moderate nutrient enrichment may be beneficial, but heavy nutrient enrichment will usually be detrimental to the ecosystem (Christman et al., 1973).

155. Increased growth as a result of nutrient enrichment can result in accelerated eutrophication in aquatic ecosystems. The demand for oxygen from decomposition may exceed the oxygen supply and depletion of oxygen may result. This will cause unfavorable environments for many cold-water fish such as trout, and other species that are intolerant of changing environmental conditions may be inhibited while more tolerant species will be favored. One common result of

eutrophication is dominance by blue-green algae. Large blooms of blue-green algae are nuisances because they float and accumulate at the surface, add undesirable tastes and odors to drinking water, and deplete oxygen concentrations in the water upon decomposition (Christman et al., 1973).

156. Toxic substances. Toxic substances are materials that enter an ecosystem and inhibit life systems. Toxic substances can be released from contaminated fill material following placement. Chemicals that are toxic to fish and other aquatic life in general include heavy metals, organo-pesticides, and various other inorganic toxicants such as ammonia, hydrogen cyanide, hydrogen sulfide, flouride, and arsenical pesticides. Toxic heavy metals include zinc, cadmium, copper, lead, chromium, mercury, silver, molybdenum, and nickel.

157. The concentration at which toxic substances will not have an adverse effect on the environment is largely unknown. It is not enough to measure the effects of a particular toxicant on one portion of the life cycle, such as the adult stage, in order to determine if that particular concentration will be detrimental (Christman et al., 1973). For example, fish could be exposed to a level of copper which would not cause death but would interfere with their life processes to a point where growth or reproduction could be inhibited. If reproduction became inadequate to meet replacement needed due to natural mortality, the total population of this particular fish would gradually decline and eventually be eliminated. Extensive literature is available on the effects of heavy metals on marine biota (Vernberg et al., 1977).

158. Lincer et al. (1976) published a review and indexed bibliography on the presence and effects of pesticides and industrial toxicants in the estuarine ecosystem. Persistence of synthetic organic compounds was found to be critically tied to biological activity, photodecomposition, volatilization, transport, state of eutrophication, temperature, and detoxification, with organo-chlorine pesticides being the most noted for their persistence. The persistence of organo-phosphates and carbonates is less well known. Bioaccumulation of synthetic organic compounds has been well documented for microorganisms, plankton, other invertebrates, fishes, and birds; but reasons for the occurrence of bioaccumulation at a particular trophic level are often not understood.

159. Changes in pH. Many natural waters are buffered against severe reductions in pH due to alkaline metals (hard water) but, in soft waters, even minor additions of acidic materials may greatly change the pH. Additionally, modifications in pH are often accompanied by other stressful factors (low oxygen, high carbon dioxide, high hydrogen sulfide, and increased levels of

heavy metals). A rise in turbidity, such as that resulting from the discharge of fill material, is likely to reduce the pH. The pH may also be lowered by release of hypolimnic water from reservoirs, by the creation of poor circulation conditions, by organic enrichment, and by chemical leaching from fills (Darnell, 1976).

160. Changes in carbon dioxide concentrations. Any increase in turbidity and sedimentation, lowering of pH, decrease in flow rate, or interference with circulation patterns from fill projects can increase the carbon dioxide concentration of natural waters. This can dramatically increase the toxicity of heavy metals and metal complexes to fishes (Darnell, 1976). The carbon dioxide concentration in water is important due to its role in the alkaline buffer system, its possible interference with respiration and behavior, and its potential for acting synergistically with other environmental factors to create stress on aquatic organisms. Even a modest shift in carbon dioxide concentration was found to completely eliminate the natural light-avoidance reaction of walleyes (Darnell, 1976).

161. Changes in oxygen concentration. Oxygen concentrations in aquatic environments can be influenced by construction activities (Taylor and Saloman, 1969; Darnell, 1976). If the placement of fill retards flow rates, increases turbidity, elevates temperatures, increases organic loads, or adds reduced chemicals, decreases in dissolved oxygen will occur.

Impacts by Type of Fill Material

162. This section will present a discussion of impacts relative to the following types of fill material: earth fill, dredged material, solid wastes, coal ash, mine tailings, and other materials.

Earth Fill

163. The physical, chemical, and biological effects of earth fill per se have not been extensively studied; however, some literature is available on the impacts of various project types. This literature is summarized in the subsection. Earth fill is used for property protection projects such as dams, dikes, breakwaters, sea walls, groins, bulkheads, and beach nourishment; for development projects such as artificial islands and sites for recreational, industrial, commercial, or residential use; and for transportation projects such as highways, railways, airports, and bridges. Characterization of earth fill material would be primarily derived from the physical, chemical, and engineering properties of the soil types involved.

164. Bhutani et al. (1975) described the scope and magnitude of water pollution problems caused by hydrologic modifications (dams, impoundments, channelization, in-water construction, out-of-water construction, and dredging). The types of pollutants released by each class of hydrologic modification were identified, and estimates were made of the relative amounts of these pollutants that enter surface waters as a result of project construction. Table 6 summarizes the relative amounts and indicates their beneficial and adverse effects on the receiving water system. The relative quantity (or release rate) of each pollutant type is shown as three levels: high (H), moderate (M), and low (L). For sediment, the release rate was estimated relative to the release rate from a predisturbed land surface (which may have been forested, grass-covered, or poorly vegetated) or a predisturbed benthic area. For other types of pollutants, the quantities released were estimated relative to the concentrations of the same type of pollutant in urban surface runoff. These estimates of quantities and rates were made by the authors, and were not based on field measurements (Bhutani et al., 1975). Table 7 indicates in greater detail the nature of specific pollutants and the expected effect.

165. In addition to construction impacts, projects using earth fill may also exhibit operational impacts. For example, operation of dams and impoundments affects the quality of downstream waters by several mechanisms (Bhutani et al., 1975):

> Trapping and retaining sediment. This alters the natural equilibrium of sediment downstream of reservoirs, causing scour and erosion. Also, trapped sediment tends with time to fill reservoirs. When accumulated sediment is dredged out, resuspension of sediment and other materials may produce abnormally high concentrations that adversely affect aquatic life downstream.
>
> Thermal stratification. Stable layers of water having different density, temperature, chemical, and biological makeup may be formed in reservoirs.
>
> Decomposition of trapped organic material. Reservoirs accumulate organic material and, upon decomposition, decreases in dissolved oxygen concentrations may occur.
>
> Nitrogen supersaturation. Violent mixing of air and water released through turboelectric generators or a high velocity tailwash causes the water to become supersaturated with nitrogen from the air. Nitrogen supersaturation may lead to undesirable effects on downstream fish populations.
>
> Surface evaporation. The large, relatively warm surface areas of impoundments permit rapid evaporation of water, thus increasing the concentration of salts and other dissolved and suspended constituents in impoundment waters.

Table 6. Effects of construction projects on water quality

CONSTRUCTION ACTIVITY	RELATIVE QUANTITY RELEASED BY CONSTRUCTION*							EFFECTS OF POLLUTANTS	
	SEDIMENT	NUTRIENTS	DISSOLVED SOLIDS HEAVY METALS	SALINITY	BIODEGRADABLE ORGANICS	REFR. ORGANICS PESTICIDES	OILS AND SYNETHETIC CHEMS	BENEFICIAL	ADVERSE
OUT-OF-STREAM ACTIVITIES (EARTH MOVING)									
• AREAL (Suburban Devm't -- residences, streets, shopping centers, parking lots, public buildings; Business/Commercial Devm't; Reclamation Land-fills -- tunneling spoil disposal,** dredging spoil on-land, earth dams. Construction -- dams, reservoir areas, bridges.) • LINEAR (Highways; Railroads; Pipelines; Power Lines; Channels/Canals/Flumes/Floodways/Drainage Ditches; Levees)	H	M	L	L	L	L	L	Sediment produced which may sustain a receptor stream at equilibrium suspended sediment load; can help remove ions in receptor water body by adsorption.	May alter the physical and biological character of the receptor water body if subjected to excessive sediment. Results in costly loss of flora and fauna, stream cross-sectional changes, altered flow regimes, and added water treatment requirements. Biostimulation of water bodies from nutrient runoff. May cause siltation of downstream reservoirs.
IN-STREAM									
• Dredging Operation/In-Water Channel Excavation, Stream Realignment	H	M	M	L	L	L	L	Suction dredging of benthal deposits may remove undesirable heavy metals and other chemical pollutants to accelerate recovery of polluted condition.	Local temporary increase in suspended sediment and turbidity with potentially damaging effects on marine life and degraded water quality for consumptive uses. Can physically remove shellfish from their habitat. Can change channel shape, ensuing scour or aggradation imposes requirements for grade control structures, concrete linings, or rip rap to stabilize the channel.
• Dredged Material Disposal in Water, In-water Fills, Causeways, Retarding Basins, Levees, Floodwalls	H	H	M	L	L	L	L	May create new land for waterfowl habitats and decrease levels of insect breeding in filled-in marshes. Stream blockages provide storm water storage and trap silt, provide fish and wildlife habitat, aesthetic improvement.	Constructed channels scour heavily during flooding. Can smother marine life on bottom, destroy fin fishes, lower dissolved oxygen levels, increase turbidity thereby reducing light transmission. Change original fish and wildlife habitat. Aquatic life stressed by temperature, and chemical and biochemical equilibria changes.
• Installation of Piles, Bulkheads, Dikes, Marinas	M	L	L	L	L	L	L		Benthic penetration and some disturbance of bottom material ensues causing local resuspension of sediments.
• Channelization (Stream Realignment, Clearing, and Snagging	M	L	L	L	L	L	L	Improves flow efficiency and navigation. BOD lower with lower detritus.	Temporarily increases suspended sediment and turbidity. May decrease concentration time of peak runoff and increase flooding downstream. Removes obstructions used by fish for protection, food support, and breeding areas.

*H (high), M (moderate), L(low) release rates are estimated relative to expected yield from predisturbed surface on benthic areas for sediment and relative to urban runoff for chemical pollutants.

**Outflow from exit considered to be a point source.

From Bhutani et al., 1975.

Table 7. Water pollution from construction activities cause/effect matrix

POLLUTANT CLASS	POLLUTANT MATERIALS	SOURCE ACTIVITIES/OCCURRENCE	QUANTITY*	EFFECTS BENEFICIAL	EFFECTS ADVERSE
Physical					
SEDIMENT	Inert and organic particles; colloids; microorganisms (Note: during transport, the sediment load comprises the suspended load plus the bed load.)	Land-Disturbing Operations: Surface-clearing, grading, excavating, trenching, stockpiling; (Note: Subsoils often have different erodibility characteristics than surface soils)	H	May provide material to maintain a receptor stream channel in equilibrium, i.e., provide adequate suspended sediment to prohibit erosive degradation of a fluvial channel, In-stream sediment required in formation of silt-laden farmlands along flood plains and near river mouths. Fine-grain sediment helps in the removal of ions which adhere to and are transported by particulates, which settle to the bottom. Dredged material disposal may also create new land areas (for building sites, beach restoration, waterfowl habitats) and decrease vectors in marsh-filling.	May exceed equilibrium suspended load of receptor stream altering many physical and biological characteristics of the channel; these include channel aggredation, silting of reservoirs, undesirable effects on marine life such as blanketing and smothering of benthic flora and fauna, altering the flora and fauna as a result of changes in light transmission and abrasion, destroying or altering the species of fish due to changes in the flora and fauna upon which the fish depend, or obstruction of their gill function. Also a need may arise for excessive treatment (sedimentation, clarification) prior to consumptive use for municipal, industrial, or irrigation purposes. Channel siltation can adversely affect its capacity to carry flood flows or support navigation and recreation. Dredged material disposal may destroy land areas (salt marshes, wildlife refuse, vegeted coverage), block flow circulation or increase vectors in the disposal area.
		Channel Modification: Dredging, waste disposal, excavation, fill, penetration of bed	M		
		Cleaning Operations: Aggregate washing, cleaning of masonry surfaces, forms, and containers	L		
Chemical					
NUTRIENTS	Ammonia, orthophosphates, polyphosphates, organic N, organic P	Fertilization of re-established vegetal cover	L	Stimulates growth of plants and grasses on areas denuded by construction (especially on slopes), thereby reducing soil loss in rain storms	Nutrients, especially from excessive application of soluble fertilizers, will be transported from new-growth surfaces at construction sites in the runoff of precipitation; by then stimulating growth of algae and marine plants, nutrients can have adverse effects on chemical exchange processes, leading to eutrophication and lowered oxygen levels. In addition to the biostimulation impacts, a large concentration of unoxidized nitrogen (organic nitrogen and ammonia) could represent a significant oxygen demand in the receiving waters.

(Continued)

* H (high), M (moderate), L (low) release rates are estimated relative to expected yield from predisturbed surface on benthic areas for sediment and relative to urban runoff for chemical pollutants.

Table 7 (continued). Water pollution from construction activities/cause matrix

POLLUTANT		SOURCE ACTIVITIES/OCCURRENCE	QUANTITY	EFFECTS	
CLASS	MATERIALS			BENEFICIAL	ADVERSE
BIODEGRAD-ABLE ORGANICS	Submerged or floating brush, lumber, tree trunks or limbs, paper, fiberboard	Improper disposal of building products or poor clearing and clean-up practices	L	Larger submerged objects may serve as a temporary habitat of fishes. Permitting growth, wood chips, and similar matter to remain in place in a future inundation area will temporarily reduce out-of-stream erosive losses by serving as a precipitation energy absorber and a sheet runoff retardent.	In degrading of the organics an oxygen demand is exerted on the receiving waters. The dissolved oxygen depression, or large resultant fluctuations in DO, can lead to death of aquatic organisms, severe changes in types and numbers of aquatic organisms, obnoxious odors, and nuisances such as aesthetic impacts, clogging of pumps, screens, etc.
REFRACTORY ORGANICS/ PESTICIDES	Highly persistent chemicals, heat resistant, or effectively nondegradable, e.g., certain pesticides and other synthetic organics (solid construction materials and tools of polyvinyl chloride, thermoplastic polyesters, rubber, and epoxy fibers and liquid chemicals for treatment of walls, adhesive applications crack-sealing, waterproofing, painting, and curing operations.) Major categories of insecticides include the chlorinated hydrocarbons--complex organic molecules of C, H, Cl--such as chlordane, malathion, DDT, and the phosphorothioates--C, H, P. Herbicides include 2, 4, D and 4, 5, T.	Improper care in construction applications, overusage, spillage. (Note: some of these types of pollutants, particularly the solids, are expected to remain at the source or point of application, with negligible overland transport). Trend in construction in use of biocides is away from inorganics and toward synthetic organics for use as insecticides, herbicides, fungicides, and fumigants.	L Note: expected level of production is very low because most pesticides are too expensive to be wastefully applied, resulting in efficient or optimal usage.	Underslab and foundation treatment with long-lasting insecticides, especially for termite control, is an important usage; herbicidal treatment of soil areas to remove herbaceous and woody plants that obstruct development and for weed control prior to revegetation is necessary in many construction projects.	Toxic to a wide spectrum of marine biota; can concentrate (by biomagnification) in aquatic organisms, and the effects can be transmitted through higher levels of the biological food chain up to humans. Most biocides show a tendancy to accumulate in bottom muds. Earth-moving may reexpose pesticides previously applied to a site, e.g., if used previously for agriculture.

(Continued)

Table 7 (continued). Water pollution from construction activities cause/effect matrix

POLLUTANT		SOURCE ACTIVITIES/OCCURRENCE	QUANTITY	EFFECTS	
CLASS	MATERIALS			BENEFICIAL	ADVERSE
DISSOLVED SOLIDS/ HEAVY METALS	Ionic Hg, Pb, Zn Mn, Co, Cr, Ag, Cd, As, Cu, Al, Fe	Derived from construction wastes such as discarded metallic frames, ducts, pipes, wiring, beams, gypsum board; also from fuels, paints, pesticides, and other construction chemicals. Also, concrete operations produce NPS, e.g., spilled cement, washing water, curing compounds.	L	A light, distributed concrete spillage or wash disposal may act as a cementitious stabilizer to reduce soil erosion; also it will add alkalinity which could correct acid soils	When these materials weather, decompose, and disintegrate (recognizing that many of the substances such as plasterboard are only slightly soluble in water), the resultant oxides and salts dissolved in water bodies may damage or destroy aquatic organisms; also higher concentrations of certain of the dissolved solids are toxic to humans.
		Dredging activities may reintroduce and disperse within the water column dormant layers (confined by silt deposits) of heavy metals trapped in bottom sludge deposits generally originating over long time periods from point industrial sources and urban runoff.	H Note: may be significant in certain sluggish rivers, lakes, or bays especially in first dredging; generally insignificant buildup would occur by the time that maintenance(repeat) dredging is undertaken	Suction dredging and disposal of undesirable chemicals in benthal deposits may accelerate recovery of polluted water bodies, in parallel with introduction of clean inflows.	Dredging may mechanically reintroduce these chemicals into waters, with subsequent diffusion and increase in undesirable impact described above.
ALKALINITY	NaCl $CaCl_2$	Produced from saline ice-removal compounds in cold climates (construction roads), dust control on graded areas, and concrete additives (freezing-depressant additives or early strength-enhancing agents, curing compounds). Affected by hydraulic changes resulting from channelization.	L Note: minor level, depending on nature and seasonality of construction activity	Use of salt compounds allows continuation of projects throughout a greater range of climatic conditions, reduces air pollution from dust	Increased salinity of water impacts upon nature of marine life (plants and animals) indigenous to the region; quality may be degraded for municipal, industrial, or irrigation uses.

(Continued)

Table 7 (Concluded). Water pollution from construction activities cause/effect matrix

POLLUTANT		SOURCE ACTIVITIES/OCCURRENCE	QUANTITY	EFFECTS	
CLASS	MATERIALS			BENEFICIAL	ADVERSE
OILS AND SYNTHETIC CHEMICALS	Petroleum products such as oils, grease, tars, asphaltic materials, fuels, solvents; paints, detergents, soaps, sealants, adhesives, chemical soil stabilizers.	Introduced into soils through improper construction and maintenance practices, (such as not using adequate caution and methods in disposing of oil wastes, transporting and transferring fuels and lubricants, oil-laden rags, and degreasing compounds), and from spills, for example, from storage tanks. Spillages during routine construction and leaks from trucks and other machinery are also serious considerations. Production of water-bitumen mixtures from road paving, roofing, and waterproofing jobs can also cause NPS concern.	L		Some of these chemicals float over water, some become entrained in water--absorbed on sediment--and some dissolve in water, but all are extremely difficult to control after entering water bodies. These categories of substances impair the use of water for drinking and for contact sports because they impart persistent odors and tastes to water. Some may block the transfer of air through a water-floating substance interface, suffocating aquatic plants, organisms, and fish. Some petroleum products contain organo-metallic compounds and other impurities toxic to fish and other organisms.
Biological					
COLIFORM	Disease-causing pathogens: soil organisms and those of human and animal origin (bacteria, fungi, viruses).	Improperly planned and managed construction sites where inadequate sanitary conditions prevail.	L M Note: Majority of biological pollutants exist in topsoil layers where they feed on dead organisms; however, construction often disturbs the lower subsoils.	Sludge from wastewater treatment plants may promote and accelerate the restoration of graded areas.	Can cause diseases in humans and animals when released or made available in water bodies.

166. Yost and Nancy (1974) studied the water-quality effects of seepage from earthen dams. Analysis of surface and seepage waters from selected floodwater-retarding structures in west-central Oklahoma showed the salinity to be several times greater than that of the impounded waters. However, the increases in concentrations of the several components were not proportional. The phenomenon appeared to be caused largely by simple solution, which is closely related to the geologic formation that provides the reservoir site and the earth fill of the dam. Concentrations of certain chemical components in the seepage water progressively decreased as the structure aged. Yost and Nancy (1974) believe this is probably a function of depletion, which is related to the amounts and solubility of the parent materials. In contrast, the concentration of other components such as iron and calcium increased with time, and the authors suggested this was due to chemical reactions in the accumulating mud on the bottom of the reservoir.

167. Fuhriman et al. (1975) evaluated the water-quality effects of diking Utah Lake in central Utah. The undiked lake has an average depth of less than 10 ft; thus large quantities of water are lost via evaporation. The proposed project would dike off two bays from the lake and reduce the area by about one-third. A computer model was developed for predicting the water quality and quantity changes associated with diking. The model is flexible and can be readily applied to other lake systems. The model calculates salt concentrations as well as the water budget, thus allowing the users to evolve better estimates of evaporation and subsurface flow. It also has the capability to predict changes in water quality and quantity resulting from various management alternatives such as changes in tributary inflow quantity and/or quality and diked-bay operational policies.

168. Madison (1970) studied the effects of a causeway on the chemistry of the brine in Great Salt Lake. During 1957-59, a permeable rockfill causeway was constructed for a railroad track across Great Salt Lake. Prior to construction, the dissolved solids content and the chemical composition of the lake brine were controlled primarily by volume changes resulting from inflow and evaporation. The causeway created two separate but interconnected lakes with different water surface elevations and densities. As a result, brine flows in both directions through the causeway, with less dense brine from the south part moving northward through the upper part of the causeway, and more dense brine from the north part moving southward through the lower part of the causeway.

Dredged material

169. Dredged material is potentially useful for industrial and residential landfill as well as for land creation for recreational facilities and wildlife habitat. A considerable amount of information on environmental impacts is already available from various dredging-related studies; therefore, a pertinent question is: how applicable to fill discharge operations is the information regarding the physical/chemical/biological impacts of dredging and dredged material disposal? With this question in mind, a survey of the dredging and dredged material disposal literature was included as part of this study.

170. Characterization of sediments. Of the many studies of the composition of sediments (dredged material discharge), the work by Mudroch and Zeman (1975) is unusually complete. They analyzed sediment samples taken from five locations in the lower Great Lakes Region. Some results of these analyses are presented in Table 8. It was noted that the mineralogical composition of the clay-size fractions ($<2\mu$) of the samples was similar; however, the abundance of several elements of concern varied considerably. For instance, the concentration of lead varied by a factor of thirty, and that of zinc by fifty. Iron, an element assumed to partially control the movement of several metals and nutrients, varied by a factor of four. Organic material varied by a factor of ten. Such variations indicate that even though fill materials may be similar mineralogically, they may have considerably different chemical impacts in operations involving the use of dredged material as fill.

171. It is emphasized that one of the main reasons for attempting to characterize material is to aid in assessing the environmental impacts from using it as fill. Adequate characterization of a fill material will require enough information to allow the prediction of the release and uptake of those components deemed important. Unfortunately in this regard, much of the available information deals with composition (e.g., elemental metals analysis). While such information is potentially useful, it is clearly not sufficient. There is not a demonstrable direct relationship between composition and the magnitude of chemical and biological impacts. For example, if dredged material contains zinc, there is the possibility of the release of zinc to the environment, but additional information is required before predictions can be made as to how much zinc would be released, at what rate, and under what conditions.

Table 8. Chemical composition of sediment samples

Parameter*	Location				
	Mitchell Bay	Hamilton Harbour	Humber Bay	Detroit River	Lake Erie
Total C	5.12	8.50	4.87	5.42	3.41
Organic C	2.85	7.01	2.85	3.65	0.78
Total P	0.09	0.36	0.19	0.10	0.11
Total N	0.10	0.33	0.21	0.13	0.05
Si	29.3	14.9	24.9	26.0	20.8
Al	3.8	3.1	4.8	4.4	5.8
Mg	2.2	2.9	1.9	2.8	2.8
Ca	6.7	7.9	8.1	7.04	8.7
Na	1.85	2.3	2.2	1.8	2.5
K	1.8	1.5	2.05	1.95	2.8
Ti	0.27	0.26	0.40	0.30	0.38
Mn	0.05	0.23	0.07	0.05	0.07
Fe	1.94	13.3	3.4	2.9	3.69
Zn	50	4,160	410	120	75
Sr	260	235	250	140	330
Pb	30	1,100	270	85	30
Cu	30	135	75	30	25

* Values for Total C through Fe are as a percentage; values for Zn through Cu are as ppm.

After Mudroch and Zeman (1975).

172. Impacts of dredged material. Numerous studies have been conducted on the physical, chemical, and biological impacts of dredging and dredged material disposal. This section will not focus on the impacts from dredging operations and the disposal of dredged material in open water or in land-based containment areas; it will focus on the impacts from use of dredged material as fill, including pertinent concerns relating to chemical leaching. Relevant chemical leaching information from open-water and land-based disposal operations will be included.

173. It must be emphasized that to a large extent, impacts are situation specific, and their relative as well as absolute importance will vary considerably. Secondly, these effects are highly interrelated, and so it can be very misleading to study them separately or in isolation. However, some categorization is necessary for purposes of discussion; accordingly, specific resultant stresses from fill creation, turbidity, oxygen-demanding materials, nutrients, organic compounds and pesticides, and metals will be presented.

174. (a) Fill creation. Creation of fill with dredged material can cause disruption of the existing ecosystem (Harrison and Chisholm, 1974). Displacement of flora and fauna in the area can occur, and as a result of changes in the land-water surface ratio, changes take place in the associated communitites of organisms (Ortolano, 1973). The dredged material may also release turbidity, toxic compounds, and other chemicals. Harrison and Chisholm also reported that vegetation died around the perimeter of an upland disposal area as a result of salt seepage.

175. (b) Turbidity. In reviewing the dredging literature prior to early 1974, Lee and Plumb (1974) identified turbidity increases as one of the principal physical problems resulting from open-water disposal of dredged material. These increases could interfere with light penetration, photosynthesis, heat transfer, and flocculation of algae; disrupt spawning beds; and bury bottom fauna and macrophytes. On the other hand, turbidity increases generally become indistinguishable within 2000 feet of the discharge site, and fall within normal fluctuations within 400 feet of disposal operations. The duration of turbidity plumes is usually short; in some studies background levels returned two hours after cessation of disposal.

176. Turbidity increases from the use of dredged material for fill creation are also anticipated to be localized and of short duration. In addition, localized natural turbidity levels may be sufficiently high so that any increases from fill sites will not represent an excessive change.

177. Slotta and Williamson (1974) commented briefly on the effect of dredging on turbidity. They noted the conclusion of other investigators that turbidity increases do not represent a significant impact. This conclusion is based on two premises: increases occur over localized areas which pelagic species can probably avoid, and periodic high turbidity levels are part of the evolutionary experience of estuaries. For instance, a 20-fold increase in suspended sediment levels caused by natural factors has been reported for Chesapeake Bay.

178. The transient nature of increased turbidity in coastal and estuarine environments is primarily due to the aggregation of fine particles into larger particles which settle faster. Windom (1976) suggested this was due to the high electrolyte content of marine waters which neutralizes surface charges on small particles.

179. (c) Oxygen-demanding materials. Oxygen-demanding materials, both organic and inorganic, can be released from fills created with dredged material. Available literature from dredging and disposal operations will be used to describe the anticipated impacts from release of oxygen-demanding materials.

180. Oxygen-demanding materials can cause depletions in dissolved oxygen concentrations and concomitant lowering of the redox potential, thus causing a shift from oxidizing to reducing conditions. Major chemical effects of decreased redox potentials include buildup of sulfides and reduction of metallic species. Several indirect effects would then occur; for example, the reduced form of many metals could form insoluble sulfides. Additionally, hydrated ferric oxide and manganese dioxide can serve as effective sorption sites for many metallic species. Reduction to the ferrous and manganous species would dissolve the hydrated oxide surfaces and possibly release other metallic species to the receiving waters. On the other hand, if reduced iron is released to the water column, it may be oxidized in the water and precipitated, with the precipitate carrying other metals to the bottom by sorption and/or entrapment.

181. Lee and Plumb (1974) summarized the oxygen depletion resulting from several dredging and dredged material disposal operations. They mentioned studies which indicated oxygen depletions of 25-30% of satuaration in New York Harbor; 25%-35% of saturation in Cleveland Harbor; 16%-83% of saturation in Arthur Kil, New Jersey; and 100% of saturation in a dredging-induced mudflow at Bellingham Harbor, Washington. Additionally, they summarized several studies relating to sediments, oxygen demand, and redox conditions. Some of the key points were

- -- Oxygen consumption by sediments is dependent on the depth and age of the sediment.
- -- Bottom deposits were found to take up oxygen at a rate independent of O_2 concentrations greater than 2 mg/l.
- -- A controversy exists regarding the interaction between sediments and dissolved oxygen. Some workers suggest that the cause of oxygen depletion is the diffusion of reduced material across the sediment/water interface, others concluded that depletions are due to oxygen diffusion into sediments with subsequent reaction.
- -- Sediments have been classified as reducing mud, oxidizing mud, and oxidate crust, and studies have demonstrated that certain trace metals are differentially concentrated in these zones. Metals such as Fe, Mn, P, Mo, Sr, and Ba had higher levels in oxidized mud and the oxidate crust, whereas As, Co, Pb, Ti, Rb, and Li were enriched in the oxidate crust. It is important to note that although several of these elements do not enter into redox reactions in natural waters, they are concentrated by co-precipitation and sorption when iron and manganese are oxidized to produce hydrous oxides. Thus, oxygen concentrations will determine the chemical form of some elements, and these forms will influence the migration of other ions.

182. In studies along the southeastern Atlantic coast, Windom (1975) found that most estuarine sediments contain high concentrations of oxygen demanding materials, particularly organic detritus. In several cases decreases in oxygen concentrations during dredging have been observed. However, the sediment may not be exposed to the water long enough to allow the total oxygen demand to be exerted. Data from field studies indicated that, in dredging, oxygen is at first depressed somewhat below ambient levels. With time, the oxygen concentrations increase as a consequence of the increase in photosynthesis brought about by the release of ammonia.

183. When upland confined disposal areas have been utilized in conjunction with hydraulic pipeline dredging, the oxygen concentration of the

effluent from these areas is commonly found to be higher than ambient. Windom (1975) again attributed this to increased photosynthesis brought about by the release of ammonia and other nutrients. Although the increase in DO of discharged waters from confined areas might suggest an improvement, the associated increase in microscopic plant population represents a potential BOD which may be exerted over time subsequent to discharge. These processes probably occur whether the material is deposited overboard or in confined areas, except that in the former case, changes are not so obvious because of dilution.

184. Lee and Plumb (1974) mentioned that oxygen depletion was observed at the interface of the mud flow caused by dredging in Mobile Bay. This was attributed to the oxygen demand of reduced inorganics in the dredged solids. The reasons given for this conclusion were the following: (1) volatile solids were not released, and (2) the rate of oxidation of volatile solids was small compared to settling time of the sediment.

185. (d) Nutrients. The release of nutrients, primarily phosphorus and nitrogen, from fills comprised of dredged material is of concern due to the potential stimulation of biological growth. Phosphorus is usually not limiting in estuarine and coastal waters, although nitrogen may be limiting (Leckie and Webster, 1973, and Windom, 1975). In freshwater environments, phosphorus may be the limiting nutrient. Pertinent literature from dredging and dredged material disposal operations will be presented since very little work has been done on nutrient leaching from fill projects.

186. The direction and rate of dissolved phosphate transport is a complex function of physical, chemical, and biological interactions. The net flow of dissolved phosphate is generally to the sediment; however, it can be transported to overlying waters under appropriate circumstances. Lee and Plumb (1974) summarized several studies of the phosphorus cycle, and some pertinent points are:

- -- In a study of the exchange of phosphate from estuarine sediments, the transfer was found to be a two-step process with half-times of 15 seconds and approximately 30 minutes. The addition of formalin decreased the amount of exchanged phosphate by 50%-100%, and this was taken as a measure of the magnitude of biological fixation. Almost as much phosphate was biologically exchanged as was exchanged chemically with clay minerals.
- -- A number of studies found that in a well-mixed system of lake sediment and water there was an appreciable release of P. The rate of exchange varied with sediment type and was greater in anaerobic systems.

-- Phosphate release was also affected by the pH of the system. In one study it was reported that phosphate sorption is favored in the pH range of 4.5 to 7.0. In four types of lake sediment (acid bog, productive, moderately productive, and unproductive), low release of P was observed below pH 7; it increased at pH 8 and above.

187. With regard to mechanisms of P transfer, Lee and Plumb (1974) pointed out that in an anaerobic environment there is an appearance of soluble iron followed closely by dissolved phosphorus at the water/sediment interface. When oxygen is introduced, the iron is oxidized to Fe(III) and it ties up the dissolved phosphorus. Other processes occur in anoxic environments which can release phosphate to the water column. Sulfate-reducing bacteria reduce sulfate to sulfide which can react with Fe(II) to form ferrous sulfides. This reaction would promote the release of phosphate. An important mechanism influencing phosphate concentrations in the water column is the tendency for phosphate to be adsorbed on sediments. The sorption mechanism is highly pH dependent, with maximum sorption occurring at pH 4 to 7. As the pH is increased or decreased, there is a rapid loss in sediment sorption capacity.

188. Nitrogen in sediments and the associated cycling has not been as extensively studied as phosphorus. Lee and Plumb (1974) indicated that nitrogen and phosphorus cycling is similar in that the transfer of nitrogen from sediment to overlying water will also be influenced by chemical form, mixing, and concentration gradients. Observed nitrogen release from lake sediment was influenced by the solid-liquid ratio, stirring, pH, and dissolved oxygen concentration. In addition, dissolved oxygen affected the form of nitrogen released. Under reducing conditions, soluble Kjeldahl nitrogen and ammonia increased for 100 days. In the presence of oxygen, the same forms were initially released but decreased to zero, probably due to oxidation to nitrate. Nitrate, which was released slowly, gradually increased for 200 days. The total nitrogen released was four times greater under aerobic conditions.

189. Windom (1975) indicated that one of the most important parameters in predicting what changes a proposed dredging operation will have on water quality is the amount of soluble ammonia in the sediment. The amount released per volume of dredged sediment should provide sufficient information to judge the magnitude of the water-quality effect on plant productivity and oxygen demand. Windom reiterated this in a more recent document (1976) describing studies of intracoastal waterway maintenance dredging. Samples around the dredge were collected and analyzed for ammonia, nitrate and phosphate, and no

increases in these nutrients were found. However, in disposal areas, nutrients were shown to increase significantly above ambient levels following dredged material deposition (e.g., ammonia may be increased by a factor of 50 or more). With time, the ammonia decreases. This decrease may be due to adsorption on particulate matter or to direct uptake by phytoplankton. Bacterial nitrification and straight chemical oxidation are two other processes that may reduce the ammonia concentration.

190. Chen et al. (1976) reported on a comprehensive laboratory study of the effects of dispersion, settling, and resedimentation on the migration of chemical constituents during open-water disposal of dredged material. Long-term studies of exchange phenomena at the water/sediment interface indicated that nitrogenous compounds were released in substantial quantities from clayey type sediments. Ammonia and organic mitrogen can be released to the range of 10 mg/l under anaerobic conditions, while nitrate and nitrite were increased to the same range under aerobic conditions. Silty and sandy type sediments were observed to release at a level 2 to 10 times lower than that of clayey sediments.

191. The association of nitrogen with clay fractions was also noted by Leckie and Webster (1973), when they pointed out that dredging reduces the capacity of sediments for nutrient binding by removing the clay and silt fraction which represents the major fraction of high surface area materials responsible for binding nutrients.

192. (e) Organic compounds and pesticides. Dredged material used for fill projects may leach certain organic compounds and pesticides. Organic compounds include both naturally occurring forms as well as oil and grease. Pertinent literature from dredging and dredged material disposal operations will be presented due to the paucity of information on leaching of these chemicals from fill projects.

193. Sediments act as a sink for organic compounds and pesticides through sorption on particulate matter with subsequent settling from the water phase. Sorption is related to the type of organic compound/pesticide, the cation exchange capacity and surface area of the particulate matter, and the were salinity, pH, and temperature.

194. After discussing the problem of organic materials in dredging operations, Leckie and Webster (1973) concluded that the question of what to do with dredged material with high contents of pesticides or other synthetic organic compounds could not be answered with any confidence. They also

pointed out that chemotactic interferences on fauna from petroleum-based materials may be a serious problem. Lee and Plumb (1974) felt that the significance of organic compounds and pesticides in sediment had not been determined, but that there was very little evidence to indicate that these contaminants become mobile once they reach the sediment. One exception to this is oil and grease, which can form surface films that selectively concentrate pesticides and other non-polar compounds. Slotta and Williamson (1974) felt that the possible adverse effects of dredged material contaminated with pesticides and PCB's are numerous; however, direct cause and effect relationships are not well documented.

195. Fulk et al. (1975) reported on a laboratory study of the release of pesticide and PCB materials to the water column during dredging and disposal operations. No significant correlation was found between sediment parameters such as silt/clay fractions and the concentration of pesticides or PCB's in the interstitial water; the amount of both materials added to a water column by dispersal of interstitial water was minor. In effect, the pesticide materials are transferred to the water column primarily by means of resuspended solids, and the concentration of the suspended pesticide material decreased with time to levels at or near background water column concentrations. Chen et al. (1976) conducted studies on the chemistry of chlorinated hydrocarbons and organo-metallic compounds as related to their availability for biological uptake.

196. (f) Metals. Toxic metals may be leached from dredged material used in fill projects. Literature from dredging and dredged material disposal will be presented due to the lack of information specific for fill projects.

197. Lee and Plumb (1974) summarized studies of the transport of metals in dredging situations by noting that under certain conditions, the sediments serve as a sink for many metals of concern. For example, the sorption of zinc, copper, chromium, cesium, and lead on particulate matter has resulted in these metals being carried to the sediment. Other metals such as iron and manganese reach the sediment due to the low solubility of their hydrous oxide forms. Conversely, the addition of particulate solids can increase the concentration of dissolved metals in lake water; for example, Cu from mine tailings in Torch Lake, Michigan.

198. The redox potential determines the distribution of metals in sediments (Lee and Plumb, 1974). For example, Mn, Ni, Co, and P were found to be concentrated in the upper oxidized layers of a sediment, but Cr, V, U, and S were enriched in the lower reduced zone. In a similar study, the elements Fe, Mn, P, Mo, Sr, Ba, Zn, Co, Pb, Ti, Rb, and Li were enriched in the oxidized portion of a sediment. The enrichment of metals such as Ba, Sr, Mo, P, Pb, Zn, and Co was thought to be due to sorption.

199. Metals leaching is controlled by the characteristics and composition of the receiving water and the solids. The most favorable conditions for the transfer of metals from sedimentary material to the water are reducing conditions in the sediment and anoxic conditions in the overlying water. The single most important factor determining the magnitude of metal concentrations resulting from leaching from sediment is the volume of water available for dilution. The fate of leached metals is a function of sorption, complexation, and redox reactions.

200. Slotta and Williamson (1974) pointed out that in sediments where sulfides are being produced, the possible chemical transformations upon resuspension become quite complex. Preliminary studies have shown that heavy metals absorb on both Fe(III) oxides and Fe(II) sulfides. From these results, it is hypothesized that heavy metals will not be released to the water column upon resuspension and either will be adsorbed, co-precipitated, or incorporated within the sulfide-bearing sediments. More research is required to elucidate the important mechanisms occurring in this process.

201. Chen et al. (1976) conducted a laboratory study on the migration of chemical constituents during open-water disposal of dredged material. Sediments were obtained from Los Angeles Harbor, and experiments were designed to ascertain both short-term and long-term metal migrations. Pertinent findings from these studies were:

- -- Concerns regarding the release of any significant quantity of toxic materials into the solution phase during dredging operations and disposal are mostly unfounded.
- -- Most of the metal concentrations in the soluble phase were well below criteria for ocean waters. With the exception of the interstitial waters, there was little correlation between data from geochemical fractionation (including gross sediment analysis) and the amount of metal release. In most cases, the redox condition and sulfide content of the overlying waters seemed to be the controlling factors. Due to the extremely low concentrations of trace

metals in seawater, the relative factor of release over the background levels should not be used as dredging criteria; instead, appropriate numerical values based on bioassay studies should be used.

202. The results of the study by Chen et al. (1976) are in consonance with the earlier conclusions of Lee and Plumb (1974) that there is no wholesale release of metals from dredged material because total concentrations do not determine transfer across the sediment/water interface. The interface is usually in an oxidized state and acts as a barrier to soluble reduced species. When a release does occur, the concentration changes are determined by the individual behavior of the elements.

203. Windom (1975) emphasized that a bulk chemical analysis of the sediment to be dredged is totally inadequate in evaluating the potential metal release from polluted sediments during dredging or disposal. He felt that the most realistic approach to evaluating the impact of a dredging operation on metal concentrations is to simply establish the amount that will be released both when the sediment is first dispersed and after it has been redeposited.

204. The main concern related to metals in dredged material used for fill is the potential resultant toxic effects. The toxic effects from land created from dredged material can occur through biotoxicity of the dredged material bank to vegetation that would otherwise colonize the land area and by leaching freshwater runoff into the estuarine system, along the tidal margins of the dredged material bank, or into the water beneath the deposited material. Toxicity can be acute or chronic (long term), and can result in reduced plant growth and/or biomagnification. Erosion could result in a rapid return of toxic materials to the estuary from which they were dredged. Erosion would be accelerated if revegetation were inhibited by toxic materials, and this would increase siltation in the receiving aquatic ecosystem (Ortolano, 1973).

205. Pollutants in and around a disposal site could conceivably become incorporated into the food chain. Windom and Stickney (1972) found that mercury, in methylated form, can become concentrated in the tissue of *Spartina alterniflora* to levels higher than the surrounding environment. The possibility that mercury from the detritus of this species could be further concentrated in estuarine and marine food chains is being investigated. Drifmeyer and Odum (1975) compared the lead, zinc, and manganese levels in sediment and common estuarine plants and animals colonizing dredged material disposal

areas with levels in the same material from a natural salt marsh. Their review of research literature on the fate of heavy metals in dredged material pond ecosystems determined that with the exception of mercury, decreasing concentrations of heavy metals with increasing trophic level seems to be a common condition in estuarine food chains. In their own study, Drifmeyer and Odum (1975) found that concentrations of lead and manganese tended to decrease markedly with increasing trophic level in both detritus-based and grazing food chains of the dredged material pond. No consistent pattern was observed for zinc.

Solid wastes

206. Municipal solid waste is used as fill for land reclamation to make recreational areas, form new harbor areas, or increase waterfront residential property. The impacts of this fill material are difficult to characterize due to the non-homogeneity of municipical solid waste. Both the physical and chemical composition depend on factors such as geographic location, economic standards of the generating community, and seasonal variations.

207. Characterization of solid wastes. It is beyond the scope of this report to include an exhaustive presentation of refuse characterization studies. A representative summary is that of Schoenberger and Fungaroli (1971) in Table 9. As with almost all fill materials, the actual composition of refuse is ultimately site specific. Further, bulk analysis of refuse does not provide an indication of the potential environmental impacts of fill operations using refuse material. On the other hand, it is not quite clear just what test(s) can be used to predict such impacts, other than fairly elaborate field and laboratory studies.

208. Impacts of solid wastes. The primary concern associated with the use of solid waste as fill is the quality of leachate waters. Numerous studies have been conducted on the characteristics of leachate waters, with most focusing on chemical constituents.

209. Schoenberger and Fungaroli (1971) investigated an incinerator residue disposal site. Their work included an analysis of the chemical composition of solid waste from the city of Philadelphia, the incinerator residue prior to landfilling, and the incinerator residue two years after landfilling. The quality of the leachate from the fill site is shown in Table 10. As can be seen, the nutrient content of the leachate was rather high, with the total

Table 9. Composition of municipal solid wastes

Item	Percentage*
Ferrous metal	10.92
Nonferrous metal	0.61
Glass and ceramics	28.41
Noncombustible inert	8.71
Rubber	0.39
Rags	4.88
Wood and cardboard	7.84
Other paper	23.32
Plastic	1.57
Animal and vegetable waste	14.35
Average percentage of moisture	30.4

*On dry weight basis

After Schoenberger and Fungaroli (1971).

Table 10. Residue leachate chemical composition

Item	Composition*
pH	8.3
Alkalinity ($CaCO_3$)	4,260
Nitrate	3.52
Phosphate	15.21
Iron	4.95
Chloride	1,803
Fluoride	5.0
Sulfate	94
Calcium	21
Sodium	3,350
Potassium	21.5
Total Dissolved Solids	7,933
BOD	125
COD	1,265
Zinc	0.95
Copper	1.15
Chromium (total)	1.53
Lead	1.16
Ammonia	47.6
Kjeldahl Nitrogen	124.7

*All results stated in milligrams per liter except pH.

After Schoenberger and Fungaroli, 1971.

nitrogen content being about 125 mg/l. The total dissolved solids content was almost 8000 mg/l, and the COD was about 1300 mg/l. The BOD was much lower than the COD, primarily because of the large concentration of heavy metals in the leachate. The principle metals were Fe, Zn, Pb, Cu, and Cr.

210. Studies of the organics in leachates have been conducted at landfills situated in or near the water table in South Dakota by Anderson and Dornbush (1975), in Illinois by Hughes et al. (1971), and in Oklahoma by Robertson et al. (1974). In another study, Cook et al. (1967) concluded that soluble materials in landfill leachate furnish inorganic elements to microflora and stimulate their growth. Soluble organic matter is also furnished to nonphotosynthetic organisms. Engelbrecht and Amirhor (1975) found that bacteria and viruses were both inactivated by sanitary landfill leachate. The capacity for leachate to inactivate these organisms varied according to pH, temperature, age of material in the fill, and the amount of leachate dilution. Cooper et al. (1975) have shown that viruses survive in solid waste leachates for several weeks.

211. While much of the work conducted to date concerns groundwater contamination, landfill leachates may also enter surface waters and adversely affect the biota. Ehlke (1975) noted that a stream above a landfill site was productive, containing a wide variety of algae, aquatic fungi, and bacteria; while below the landfill site the stream supported only a few organisms under extreme conditions.

Coal ash

212. Coal ash residue consists of bottom ash collected from utility boilers and fly ash collected by air pollution control equipment. Fly ash consists of many small (0.01-100 micron diameter), amorphous, glass-like particles of a generally spherical character. Coal ash has been primarily used as a mineral filler material for concrete highways and other construction projects. Increased use of both bottom ash and fly ash is expected for projects involving the development of marginal and/or submarginal lands. Fly ash has been proposed for use in large-scale reclamation projects in surface-mined areas.

213. Coal ash may be used as a fill directly; more often it is placed in a pond and later mined as fill material. Since both methods minimize the

resuspension and release of particles into water systems, the prime environmental concern is from leaching. The discussion which follows is primarily related to the characteristics and potential impacts resulting from the use of fly ash in fill projects.

214. Characterization of coal ash. A considerable amount of information exists on the composition of coal ash material. Rohrman (1971) summarized data from several sources and the results are shown in Tables 11 and 12. Table 11 presents a general analysis of the constituents in coal ash, while Table 12 identifies potential water pollutants. Heavy metal concentrations in coal ash are summarized in Table 13 (Weeter, Niece, and Digioria, 1974).

215. Theis et al. (1976) pointed out that while it is important to know the total metal content of fly ash materials, it is perhaps even more important to determine the fraction of these metals actually available to the environment. In order to study potential leaching, three extraction procedures were chosen for the analysis: digestion with hydrofluoric acid and aqua regia to give total metal values; ammonium oxalate to give values for metals associated with the oxides of iron, aluminum, and manganese; and hydroxylamine hydrochloride to give values for metals associated with manganese oxides. Metals associated with the various oxide forms were studied since during the combustion process, many different metal oxides become concentrated on the ash spheres, forming a surface coating. The composition of this coating is highly variable from ash to ash and is primarily responsible for the alteration of aquatic receiving systems. Moreover, some oxides (e.g., Fe, Al, and Mn) can act as reservoirs for several metals (Theis et al., 1976). The results of the extraction are shown in Table 14. The amorphous oxides of iron exerted the primary control on most of the metals and ashes studied. However, Cd, Ni, and Pb seemed to exhibit a preference for the manganous oxide surfaces.

216. Theis et al. (1976) suggested that the relative amounts of trace metals within and on the surface of ash particles are due primarily to combustion temperatures and the distribution of the metal among the various mineral forms prior to combustion. However, since little is known of the chemical behavior of trace metals at high temperatures, such suggestions are largely speculative. It would seem, however, that even at the high temperatures involved, trace element behavior is governed to a large extent by the thermodynamic properties of the oxide sink with which they become associated.

Table 11. Composition of power plant coal ash

Constitutent	% by weight
Silica (SiO_2)	30-50
Alumina (Al_2O_3)	20-30
Ferric Oxide (Fe_2O_3)	10-30
Lime (CaO)	1.5-4.7
Potassium oxide (K_2O)	1.0-3.0
Magnesia (MgO)	0.5-1.1
Sodium oxide (Na_2O)	0.4-1.5
Titanium dioxide(TiO_2)	0.4-1.3
Sulfur trioxide (SO_3)	0.2-3.2
Carbon (C) and volatiles	0.1-4.0
Boron (B)	0.1-0.6
Phosphorus (P)	0.01-0.3
Uranium (U) and thorium (Th)	0.0-0.1*

*From coals east of Mississippi River

After Rohrman, 1971

Table 12. Concentration of potential pollutants in dry ash from 12 power plants

Phosphorus, ppm	Nitrogen in NH_3, mg/l	Nitrogen in NO_3 and NO_2, mg/l	Radioactivity, Alpha	pci/mg Beta
80-230	<0.1	$\sim$2	26 $\pm$ 5	71 $\pm$ 7
20-90	<0.1	$\sim$2	56 $\pm$ 8	109 $\pm$ 9
30	0.1	$\sim$2	37 $\pm$ 6	91 $\pm$ 8
1-70	0.1	$\sim$2	52 $\pm$ 7	81 $\pm$ 8
1-60	<0.1	$\sim$2	20 $\pm$ 5	40 $\pm$ 6
20-30	0.1	$\sim$2	36 $\pm$ 6	88 $\pm$ 8
1	<0.1	$\sim$2	15 $\pm$ 4	50 $\pm$ 7
10	0.2	$\sim$2	35 $\pm$ 6	82 $\pm$ 8
50	0.2	$\sim$2	30 $\pm$ 6	61 $\pm$ 7
60	0.2	$\sim$2	41 $\pm$ 7	75 $\pm$ 7
90	<0.1	$\sim$2	51 $\pm$ 7	164 $\pm$ 10
150	0.1	$\sim$2	28 $\pm$ 6	72 $\pm$ 7

After Rohrman, 1971

Table 13. Heavy metal concentrations in fly ash and bottom ash

Constituents	Fly Ash, ppm	Bottom Ash, ppm
Arsenic (As)	8-120	2-250
Cadmium (Cd)	0.01-8	0.01-15
Cesium (Ce)	100-8000	15-800
Cobalt (Co)	7-90	20-80
Chromium (Cr)	90-120	80-150
Copper (Cu)	90-150	0.01-300
Mercury (Hg)	0.7-0.15	1-2
Magnesium (Mg)	1,200-50,000	10,000-30,000
Manganese (Mn)	110-150	150-200
Sodium (Na)	1,200-12,000	2,000-8,000
Nickel (Ni)	110-150	150-250
Lead (Pb)	110-150	150-250
Tin (Sb)	0.01-15	2-15
Selenium (Se)	25-75	3-10
Titanium (Ti)	9,000-20,000	5,000-15,000
Vanadium (V)	115-150	100-300

After Weeter, Niece, and Digioria, 1974

Table 14. Trace metals in fly ash (all values in µg/g of fly ash)

Metal	$HF - HNO_3$ Extraction		Oxalate Extraction		Hydroxylamine Hydrochloride Extraction	
	Mean	Std. Deviation	Mean	Std. Deviation	Mean	Std. Deviation
Arsenic	157	348	146	302	4.5	4.2
Cadmium	8.1	3.9	1.0	0.6	2.0	3.4
Chromium	109	77	48	70	15	24
Copper	97	95	47	51	16	27
Lead	157	320	12	15	11	17
Nickel	220	138	24	29	21	22
Zinc	515	933	156	351	67	177

After Theis et al., 1976

217. Impacts of coal ash. The potential chemical and biological impacts from the use of coal ash as fill material are related to depletion of dissolved oxygen, changes in pH, and release of trace metals. Depletion of oxygen would have an adverse effect on fish and zooplankton in general and on the species composition of bacteria and other microorganisms; the population of anaerobic microorganisms would probably be enhanced. The pH changes could cause elimination of certain species of fish, with some effects on the species composition of macroinvertebrates, phytoplankton, vascular plants, and benthic organisms. The release of several trace metals, including cadmium, chromium, cobalt, copper, iron, lead, nickel, zinc, and perhaps mercury may occur. Any or all of these may be toxic to certain species in the environment and could undergo bioaccumulation and biomagnification in the ecosystem.

218. It was suggested by Theis (1975) that the depletion of dissolved oxygen was due to the presence of sulfite, an effective oxygen scavenger via the reaction:

$$SO_3^{2-} + 1/2\ O_2 \rightarrow SO_4^{2-}$$

This reaction, which is slow under ordinary conditions, is catalyzed by the presence of even small amounts of Fe^{2+}/Fe^{3+} or Co^{2+}/Co^{3+}, both of which are usually present in coal ash. The pH changes could be either acidic or basic, depending on the nature and history of the material (Theis, 1975). The characteristics which appeared to be most responsible for pH changes were oxalate-extractable iron (acid content) and soluble calcium (base content).

219. The actual amounts of metals which are released from fly ash will depend largely on the manner in which the metals are held to the fly ash, their chemical form, and the chemical properties of the water with which the fly ash comes in contact (Theis, 1975). Water characteristics such as pH, CO_2, presence of ligands, and redox potential, and the ion exchange and sorptive properties of local solid phases, are all factors that could be expected to affect the ultimate equilibrium state in a given environment. In order to study the short-term release of trace metals by fly ash to aqueous receiving systems, Theis et al. (1976) subjected varying amounts of materials to selected pH washings. The results are shown in Table 15. The desorption generally followed a predictable pattern of decreasing release with increasing pH; therefore, the greatest environmental concern would be with those ashes

Table 15. Metal release from fly ash as a function pH

Metal \ pH	3	6	9	12
Arsenic	51.9*	1.0	0.80	72.9
Cadmium	1.1	0.4	0.15	0.2
Chromium	9.4	1.9	2.0	2.4
Copper	9.4	0.8	0.36	0.6
Lead	9.1	1.4	0.73	0.9
Nickel	11.7	3.6	0.50	0.6
Zinc	25.7	8.3	0.26	1.7

*Values shown are in μg/g of fly ash.

After Theis (1976)

which produce a low pH, or with those receiving waters having a low pH. Further studies by Theis et al. (1976) indicated that desorption curves were generally U-shaped when plotted versus pH, thus suggesting that trace metal solubility is pH controlled.

220. In addition to trace metals, large amounts of chlorides and sulfates can be released from coal ash, and it is possible that soluble inorganic complexes are formed. It is noted that this is an example of the need for more definitive information on complex formation in natural aquatic systems.

22. Rohrman (1971) analyzed the general effects of fly ash on water quality. Phosporus, nitrogen, boron, and certain radioactive elements were identified as being of particular importance. The possible presence of mercury is also of concern.

222. Weeter et al. (1974) conducted laboratory bench-scale experiments to determine what ash-washing period could be utilized in order to reduce the ash chemical load to the landfill, but within the constraint of not exceeding water-quality criteria for the wash water. A second question was how long can one expect ash fill leachate quality to exceed water-quality criteria. Table 16 indicates that leachates from the coal ashes studied would in all probability exceed water-quality standards for more than one item (e.g., iron, sulfates, total dissolved solids, and pH). Studies of leachates from two existing, partially completed ash fills are summarized in Table 17. Sulfates, total iron, TDS, pH, and Mn did not meet existing water-quality standards.

223. Further studies were conducted to determine release rates and times of release of various components under batch mix conditions (Weeter, Niece, and Digioia, 1974). Data indicated that under the conditions of the study, one hour would be sufficient for mixing to arrive at a steady state supernatant liquid concentration for the various parameters. To meet a water-quality criteria of 250 mg/l of sulfates, the load of a particular ash had to roughly 40 grams of ash per liter of wash water at one hour mixing time. As an example of applying this data to a real situation, they assumed a 100-foot-deep fill of a particular ash covering 1 acre. This particular ash required 36 gallons of wash water per cubic foot before the wash water met quality standards. This meant that 1.55×10^8 gallons, or 492 acre-feet of water would be required to pass through the fill before an effluent sulfate concentration of 250 mg/l or less is attained. If

Table 16. Chemical characteristics of coal ash shake test supernatant*

Parameter	Fly Ash**	Bottom Ash**	Water Quality Criteria
Total Iron (Fe)	0.1-1.8	0.05-0.15	1.5
Potassium (K)	33-112	0.4-6.6	
Calcium (Ca)	400-600	8-135	
Magnesium (Mg)	1-19	0.8-7.1	
Titanium (Ti)	Trace	<0.1	
Arsenic (As)	<0.01	<0.1-0.8	
Boron (B)	3-10	<0.1-0.2	
Aluminum (Al)	1.5-6.8	<0.05-0.5	
Sodium (Na)	15-90	0.8-7.8	
Sulfate (SO_4)	1300-2000	12-60	250
Phosphate (PO_4)	0.1-0.6	0.1-0.5	0.4
Silica (Si)	3-40	1-2	
Total Dissolved Solids(TDS)			500 (avg)- 750 (max)
pH			6.0-8.5

*500 grams of ash with 2 liters of distilled water; shaken for 48 hours.
**All values are in mg/l except for pH.

After Weeter, Niece, Digioia (1974)

Table 17. Chemical properties of discharge from an existing ash disposal site

Parameter	Range of Measures
Chemical Oxygen Demand (COD)	23 mg/l
Total Dissolved Solids (TDS)	3000-3800 mg/l
Total Iron (Fe)	18-200 mg/l
Manganese (Mn)	15-19 mg/l
Calcium (Ca)	139-424 mg/l
Magnesium (Mg)	100-400 mg/l
Ferrous Iron (Fe^{+2})	0.5-4.0 mg/l
Aluminum (Al)	12-33 mg/l
Sulfate (SO_4)	1200-1800 mg/l
Chloride (Cl)	40-50 mg/l
Fluoride (F)	0.5 mg/l
pH	2.9-3.7
Specific conductance	2100-5500 mhos

After Weeter, Niece, Digioia (1974)

15 inches of water per year passed through the fill, approximately 400 years would be required. The implication is that for optimal fill management, either the system should be made impermeable to surface water percolation and therefore prevent leachate generation, or the system should be made very permeable in order to leach materials from the ash in a short time and therefore require a treatment process for a short period. The authors pointed out that the latter method is not presently practicable.

224. In additional work, Theis et al. (1976) considered the movement of some heavy metals in fly ash-soil environments. The rationale was that once a metal is released into the aquatic environment via leaching, it comes into contact with the existing soil system. Of concern was the sorption of individual metals on the soil, and the long-term attenuation of concentration with distance. The general procedure consisted of leaching fly ash with distilled water overnight, adjusting the pH for reduction of iron levels, filtration (0.45 microns), addition of desired amounts of trace metals (as nitrates), adjustment of pH, and mixing with a known amount of previously dried soil. Reaction vessels were agitated for 12-15 hours, filtered, and analyzed for residual trace metal concentrations. Data were typically expressed as adsorption isotherms. The soils studied included a clean silica sand, bentonite clay, organic peat, and a natural sand with calcium and iron impurities. The authors emphasized that "natural" ash leachate was used, and therefore the gross effect of ionic strength and inorganic complex formation was contained in the data collected. However, it is not clear how distilled water with pH adjustment can be considered to provide a "natural" leachate. Generalizations made by the authors (Theis et al., 1976) from the data include:

-- Sorption by various soils generally increases as the pH of the aqueous phase increases. Bentonite sorption was least affected by pH changes, and organic peat most affected. Bentonite is negatively charged throughout the pH range used, and so sorption changes were attributed to changes in metal speciation with pH. Organic peat contains many ionizable organic functional groups with pH values from 3 to 6; hence its surface characteristics would be highly pH dependent.

-- The ranking of soil sorption capacity was

organic peat > bentonite > calcite sand > silica sand.

-- The ranking of metals studied on order of adsorptive tendencies was

$$Cr > Cu > Zn > Cd.$$

Mine tailings

225. Concern has been expressed in recent years about the deleterious effects on water quality and aquatic organisms caused by drainage from mine tailings. Mine tailings are not normally used as fill; however, with the current energy crisis, coal mining and associated tailings are expected to increase in the next decade, and with this increase the usage of tailings for fill is expected to increase. It should be noted that this discussion includes both coal mine and various mineral mine tailings. Due to the similarities of concerns, information is also included on acid mine drainage.

226. Characterization of mine tailings. A number of studies have been made on the chemical composition of mine tailings, but here again it is dangerous to extrapolate or generalize because the composition will be strongly site specific. A representative study is that reported by Galbraith et al. (1972) near Cataldo Mission, 14 miles southeast of Coeur d'Alene, Idaho. This region has long been important for its silver, lead, and zinc mines, with copper and cadmium as important by-products. They digested the mine tailings samples with nitric acid and analyzed the supernatant via atomic absorption. Representative data for several metals and other elements is shown in Table 18.

227. Impacts of mine tailings. McWhorter (1975) reported on a study to identify potential water-quality problems associated with runoff and percolation through mine tailings at selected sites in the Upper Colorado River Basin. The introduction of soluble salts into receiving waters is probably the most significant water-quality problem. No significant release of heavy metals was observed in the coal mine tailings studied; however, some significant heavy metal concentrations (Mn, Pb, Zn) were observed in the stream below the tailings area at a copper-lead-zinc mill. The quality of percolate and runoff was found to correspond to the constituents of extracts prepared from saturated pastes of the tailings material. A method of estimating salt introduction into receiving waters was developed and found to agree with the measured salt release at one coal mine tailings area.

228. Martin (1974) studied the quality of effluents from coal refuse piles, including seeps, direct runoff, and adjacent ponds, as well as the water quality in receiving streams. The pH values ranged from 2.4 to 6.9 for

Table 18. Chemical analysis of mine tailings at Cataldo Mission, Idaho.

Chemical Constituent	Range of Concentrations	
	3 ft.*	6 ft.**
Zn (%)	0.11-1.60	0.04-0.06
Pb (%)	0.12-1.31	0.02-0.08
Mn (%)	0.14-1.88	0.03-0.25
Fe (%)	2.0-17.2	1.20-2.25
Cu (ppm)	40-261	21-38
Ag (ppm)	1.7-40.5	0.5-0.6
Ca (ppm)	105-950	175-250
Na (ppm)	45-175	40-135
K (ppm)	150-725	380-850
Mg (%)	0.26-0.66	0.27-0.31
pH (units)	6.00-7.45	5.00-5.80

* 30 samples in group
** 3 samples in group

After Galbraith et al. (1972)

seeps and direct runoff. With the exception of local concentrations of particular ions, metals, and sulfate concentrations varied directly with acidity. However, a direct correlation of ion concentration with acidity was not established. Martin (1974) noted that sediments eroded from refuse piles may cover aquatic breeding and feeding areas, thus sediments are more potentially damaging than heavy metals or acids.

229. Quantitative estimates for acid mine drainage emissions to surface waters can be made via a source-to-stream approach or a stream-to-source approach (McElroy et al., 1976). In the source-to-stream approach, the loading function describes the potential acid formation from a statistically "typical" mine, and allows for the neutralization of part of the acid by background alkalinity. The function depends on knowledge of the number of mines in various categories and upon the neutralization potential of the background. In the stream-to-source approach, the loading function for acid mine drainage is based upon comparison of sulfate loadings in streams to sulfate contributions from background and point sources. It does not allow for neutralization of acid mine drainage between the point where it is formed and the point where it is discharged. Loading functions were also presented for heavy metals and radioactive materials from abandoned mine sites, chat piles, and tailings piles.

230. Massey (1972) studied the pH and soluble Cu, Ni, and Zn in eastern Kentucky coal mine tailings. The concentrations of Fe, Al, and Mn in the leachates were found to be related to pH. Liming of mine tailings should reduce the concentrations of these ions in solution, but the multiplicity of factors involved prevents direct calculation of the pH effect. Of the three elements studied, Ni appeared to be most likely to remain in the tailings in toxic amounts once the pH has been adjusted to a point which would otherwise be satisfactory for plant growth.

231. As a mechanism for the observed behavior, Mink et al. (1972) proposed that metals leaching by ground water passing through mine tailings is caused by the oxidation of sulfides through the action of microorganisms. The pH of the ground water is produced by mechanisms within the tailings system itself. Action of sulfide- and sulfur-oxidizing bacteria causes the formation of sulfuric acid, thereby increasing the H^+ and SO_4^{2-} concentrations. Metal ions go into solution as metal sulfates, and the concentration of

H_2S increases by the interaction of H^+ and S^{2-}. Increases in H_2S create an environment suitable for the growth of sulfate-reducing bacteria which convert sulfate to sulfide and simultaneously precipitate metal sulfides at a pH near 6.6. A decrease in pH with depth destroys sulfate-reducing bacteria, and dissolution and leaching of the tailings increase. Where O_2 is sufficient, iron oxidizing bacteria oxidize Fe^{2+} to Fe^{3+}, and an insoluble hydroxide is formed. Consequently, very little Fe is found in ground water coming from the system.

232. Gambrell et al. (1976) discussed some of the physicochemical parameters that regulate mobilization and immobilization of toxic heavy metals. In general, a moderately low pH and redox potential environment favors the relatively bioavailable soluble and exchangeable chemical forms of metals, while sparingly soluble, oxidized compounds predominate at higher pH and oxidation levels. Important regulatory mechanisms affecting heavy metals include adsorption by cation exchange reactions; metal precipitation as insoluble sulfides under strongly reducing conditions; formation of discrete metal oxides and hydroxides of low solubility; adsorption to colloidal Fe and Mn oxides in aerobic, neutral, or alkaline environments; and complexation with soluble and insoluble organic matter at all levels of pH and redox potential. Chelate formation with soluble organic compounds may enhance heavy metal solubility to levels considerably greater than the concentration of soluble free ions. Conversely, complexation with insoluble organics is an important sink for many metals. Redox potential influences both of these processes by quantitatively and qualitatively affecting the organic compounds present.

233. There are numerous published references on the effects of drainage from mine tailings on aquatic life including fish, riparian and aquatic vascular plants, bottom-dwelling invertebrates, periphyton, phytoplankton, aquatic insects, and microorganisms (Parsons, 1968; Roback and Richardson, 1969); Nash, 1970; Warner, 1971;Branson and Batch, 1972; Hill, 1972; Koryak et al., 1972; Davis, 1973; Savage and Rabe, 1973; and Warner, 1973). The most commonly cited effects include:

(1) Fewer numbers of species present,

(2) High numbers of individuals within the species that were present,

(3) Fish either reduced or absent,

(4) Certain species very susceptible to elimination by acid drainage, while others were more resistant.

234. Studies with fish indicate that death occurs when the pH remains at 4.0 or less for any length of time (Parsons, 1968; Branson and Batch, 1972; and Davis, 1973). As streams progress further from the acid source and the pH values increase above 5.0, fish species return to the stream. Fish are also affected by the formation of ferric hydroxide which inhibits the growth of benthic algae. Secondary producers such as invertebrates are deprived of their food supply, the benthic algae, and are therefore not available as food for fish.

235. Roback and Richardson (1969) found that under conditions of constant acid mine drainage in western Pennsylvania, the insect orders odonata, ephemeroptera, and plecoptera were commonly eliminated at pH values of 3.3 to 4.4. The trichoptera, megaloptera, and diptera were reduced in a number of cases. The nonbenthic hemiptera and coleoptera were little affected and developed large populations in the locations damaged by the mine drainage. Under intermittent acid mine drainage, a diverse but slightly depressed insect fauna developed.

236. Koryak et al. (1972) found that in the area of immediate pollution the effects of acid mine wastes on benthic fauna were similar to the effects of organic pollution in that there were high numbers of individuals but few species present. In the zone of active neutralization, in which there was the deposition of iron hydroxide, species diversity increased slightly but the biomass was very low, thus indicating suppression of biological growth by the acid mine pollution.

237. The biological recovery of a stream polluted by mine tailings was investigated by Simmons and Reed (1973). The presence of sulfuric acid caused a reduction in fish species and macrobenthic fauna. In this area the mussel population could not establish itself. Consideration of only the insect portion of the macrobenthic community would indicate that the river recovered very quickly. However, when the entire macrobenthic community was considered, recovery was much slower. Mussel populations did not become reestablished until much further downstream.

Other materials

238. Artificial reef reconstruction from such materials as scrap rubber, tires, car bodies, construction wastes, and baled municipal solid wastes

has been suggested. Small artificial reefs serve to concentrate fishes and thereby temporarily improve sport fishing. Large reefs may support commercial fishing and are thus beneficial. Rounsefell (1972) reported that artificial reefs constructed on concrete, tile, brick, quarry stone, or large rubble would be desirable in several locations; wood is undesirable in that it is very quickly riddled and disintegrates; and the thin steel of car bodies rusts away in about three years. The use of garbage in the construction of artificial reefs should be avoided.

239. Rounsefell (1972) reported on a study of two sections of similar shoreline in Clear Lake, Texas. One section was left as a natural gradually sloping shore covered with marsh vegetation, chiefly Spartina; a rock bulkhead was constructed at the second site. During ten months of sampling it was found that the natural shoreline produced 2.5 times more brown shrimp and 14 times more white shrimp than the altered shoreline. This is an example of how easily the productivity of an estuarine nursery can be altered.

240. Sludges from water treatment plants, sewage treatment plants, industrial processes, and pollution control systems may be disposed of in sanitary landfills or chemical landfills. There is minimal literature on the use of these sludges as fill materials. It can generally be concluded the runoff from sewage sludge or other organically-rich fill sites will contain organic compounds, inorganics including heavy metals, and nutrients. The quality of runoff from inorganically-rich fill sites will be dependent on the type of sludge and many other factors.

Evaluation Techniques

241. Two basic tests are potentially useful for identifying anticipated environmental impacts from the discharge of fill material --- the Elutriate Test and the bioassay test. Unfortunately, both tests have limitations and the data available on the evaluation of fill materials are fragmentary. The amount of testing which would be appropriate prior to permit issuance will vary according to the size and importance of the project, the importance of the fill site, and the type of fill material used. In some cases, little or no testing will be needed, such as in the use of a non-polluted fill material

in an ecologically well-known area. Conversely, extensive testing may be required for polluted fill material to be used in ecologically sensitive areas. Testing associated with the engineering properties of the material is discussed in Appendix G.

Elutriate Test

242. Early studies of the chemical impacts of dredging suggested a relationship between the chemical nature of the sediments and their toxic and biostimulatory potential. Results of these studies prompted the EPA in 1971 to adopt bulk sediment analysis results as criteria for determining the acceptability of dredged material for disposal into the nation's waters. At the time, very little information on the water-quality effects of dredging in coastal and estuarine waters was available.

243. Promulgation of the criteria almost immediately generated criticism from several workers and institutions. Boyd et al. (1972) presented a fairly comprehensive criticism as of the fall, 1972. They commented in detail on the selection of parameters, sampling, analytical techniques, and interpretation of results required by the 1971 EPA criteria, and pointed to serious shortcomings in all these areas. Lee and Plumb (1974) stated that "...it must be presumed that the authors of these criteria assumed that there is some relationship between the bulk sediment composition and the pollutional tendencies of the sediment." In their opinion, the literature review EPA presented demonstrated that there "...is little or no evidence to support this premise." Keeley and Engler (1974) provided a succinct summary of the disadvantages of the 1971 EPA criteria as follows:

(1) Little or no known correlation exists between the concentration of various chemical constituents within sediments subject to dredging and disposal operations and consequent effects on water quality,

(2) Several of the listed variables, most notably volatile solids and chemical oxygen demand, provide little meaningful information when applied to sediments, especially marine sediments.

244. Further criticism of bulk sediment analysis results was made by Windom (1975) when he stated "...in evaluating the potential metal release of polluted sediments during dredging, a bulk-chemical analysis of the sediment to be dredged is totally inadequate. The most realistic approach to evaluating the impact of a dredging operation on metal concentrations

is to simply establish the amount that will be released both when the sediment is first dispersed and after it has been redeposited." In 1976 the same basic opinion was repeated (Windom, 1976).

245. As a result of these criticisms and the need for a better test, conversations between the Corps of Engineers and the EPA led to a new approach to disposal criteria--the Elutriate Test (Federal Register, Vol. 38, No. 198, 1973, pp. 28610-28621). As defined in the Test, dredged material will be considered unpolluted if it produces a standard elutriate in which the concentration of no major constituent is more than 1.5 times the concentration of the same constituent in the water from the proposed disposal site used for the testing. The 'standard' elutriate is the supernatant resulting from the vigorous 30-minute shaking of 1 part bottom sediment with 4 parts water from the proposed disposal site followed by 1 hour of letting the mixture settle and appropriate filtration or centrifugation. Major constituents are those water-quality parameters deemed critical for the proposed dredging and disposal sites, taking into account known waste discharges in the area and their possible presence in the dredged material. The 1.5 factor of the original test has been found to have no sound technical basis, thus is has been deleted from the recent modifications of the test. (Federal Register, Vol. 40, No. 173, Friday, 5 September 1975, pp. 41292-41298).

246. Lee et al. (1975) carried out a comprehensive study of the factors influencing Elutriate Test results. Test operating parameters which were investigated included filtering, sample size, method and time of agitation, oxygen concentration, amount of sediment in the elutriate mixture, type of water, and settling time. Chemical constituents which were examined included ammonia, phosphorus, iron, manganese, copper, lead, zinc, cadmium, selected chlorinated hydrocarbon pesticides (aldrin, DDT, DDD, dieldrin, endrin, heptachlor, lindane, methoxychlor) and polychlorobiphenyls. Some of the pertinent findings of the study were:

-- The test procedure did not define the conditions of mixing sufficient to ensure a well-defined oxygen concentration for the test period. At the same time, the oxygen content of the elutriate was found to be one of the most important factors influencing the release of chemical contaminants from dredged sediments. Therefore, compressed air agitation should be used during the 30-minute test period.

-- Varying the length of the shaking period did not significantly affect the heavy metals released in the elutriate test, nor the amount of ammonia and orthophosphate transferred.

-- The volume of the elutriate obtained within a reasonable period of time using the 1:4 ratio of sediment to disposal site water is insufficient to detect chlorinated hydrocarbon pesticides at the sensitivity required. Therefore, use of 5% sediment of the total elutriate volume rather than 20% sediment was suggested.

-- Substantial amounts of ammonia were released from each of the sediments studied. The amounts appeared to be related to the total nitrogen present in the sediments. The amounts of ammonia and manganese released were potentially sufficient to cause acute lethal toxicity, for certain organisms, under conditions of little or no mixing.

-- Large amounts of orthophosphate were sometimes released under anoxic conditions, but many samples tested showed uptake of orthophosphate from the disposal site water by the dredged sediments. This uptake was attributed to sorption on hydrated ferric oxide surfaces.

-- There was little or no relationship between the bulk heavy metal content of sediment and the amounts released during the Elutriate Test. Manganese was the only metal released in potentially significant amounts from dredged sediments during the Elutriate Test. In general, for all the sediments tested, zinc was decreased during the test from that originally present in the test water. Copper, cadmium, lead, and iron generally showed no change in the filtered elutriate from that originally present in the test water.

-- Bioassays should be conducted with various organisms for both ammonia and manganese using concentrations and exposure times which simulate conditions at open-water dredged material disposal sites. A benthic organism bioassay test should be developed to assess long-term effects of chemical comtaminants present in dredged sediments once these sediments have been redeposited at the disposal site.

247. More recently, Lee, Lopez, and Piwoni (1976) pointed out that the Elutria Test has been modified to include use of dredging site water rather than disposal site water for freshwater dredging. This modification is based on the fact that it is actually dredging site water that will affect the initial migration of chemicals from sediments during dredging. Disposal site water is still used for evaluation of marine dredging; however, Lee, Lopez, and Piwoni (1976) felt that this is technically incorrect.

248. O'Connor (1976) also reported on investigations of the Elutriate Test. High concentrations of dissolved zinc occurred when the pH of sediment-water mixtures was allowed to remain at the low levels created by the testing procedure. If the pH was adjusted to a value characteristic of natural conditions, zinc was not solubilized. The testing procedure was also found to create anoxic conditions and to produce high levels of dissolved ferrous ion. Upon aeration, a ferric hydroxide precipitate forms which can scavenge heavy metals from solution. Additional study indicated that the zinc release was inversely related to the clay-sized fraction of the sediment. It was hypothesized that the presence of the increased surface area favored the retention of heavy metals with the solid phase.

249. In summary, the Elutriate Test is a second generation attempt to predict the impacts of dredging operations. More information is needed on the reliability of test results for dredging operations. The applicability of the Elutriate Test for evaluation of the anticipated environmental impacts of fill discharge operations is simply unknown. The conditions of the Test do not necessarily match the conditions at a fill discharge site. Moreover, due to the above-stated limitations of the bulk sediment analysis results, this approach for evaluating fill material is not considered acceptable. Accordingly, research is needed on the applicability of the Elutriate Test or the development and evaluation of an appropriate test procedure, for ascertaining the potential releases of fill material components.

Bioassay test

250. There is little information available on the short-term effects of pollutants on aquatic organisms (Environmental Effects Laboratory, 1976). Therefore, in situations where such information is important, it is necessary to perform bioassays on appropriate organisms. At the present time, this is the best technique available to simulate such effects as toxicity, stimulation, inhibition, or bioaccumulation (Environmental Effects Laboratory, 1976). Bioassay procedures for ocean disposal of wastes have been developed by the EPA (Environmental Research Laboratory, 1976), and a dilution technique for bioassays in relation to dredged material disposal has been developed by the Corps of Engineers (Plumb, 1976). No information is available on the applicability of the bioassay test to fill material evaluation.

251. Bioassays are generally more expensive, difficult, and time-consuming than chemical analyses because a healthy supply of test organisms

must be maintained; elaborate controls are often needed to ensure that the observed results are caused by the material being tested and not by the condition of the organisms, the equipment, or any accidental contaminations; and a long testing period is often required (Environmental Effects Laboratory, 1976). One of the most critical issues is the selection of test organisms. Selection should be based on presence at the fill discharge site as well as on the anticipated effects of the filling activity. An algae bioassay may be desirable, for example, if the eutrophication potential of a fill material is of concern. It is important to select the appropriate life stage of the organisms tested. Some researchers have shown that effects on the embryonic stages of an organism are generally more acute than on more mature stages (Waldichuk, 1973). At the present time routine and generally acceptable procedures for bioassay of benthic organisms are not available (Environmental Effects Laboratory, 1976).

252. Two types of acute bioassays, static and continuous flow, may be conducted. In general, the continuous flow bioassay, in which the pollutant is being continuously replaced by a constant inflow, is preferred over the static bioassay (Waldichuk, 1973). Long-term or chronic effects of pollutants can also be examined by bioassay. Similar considerations as to selection of organisms and appropriate life stages are important in acute as well as chronic bioassays. In addition, the problem of acclimation may arise for some pollutants. Acclimation in this context refers to increasing resistance to a pollutant over time (Waldichuk, 1973). With some pollutants, exposed test organisms may display a delayed reaction and die some time after the tests are concluded. It is therefore important to watch for any post-testing biological changes.

253. Extreme care should be taken in extrapolating laboratory results to the field because any laboratory study is a simplification of the field situation. The exposure time and concentration of a pollutant may be altered continuously in the field, whereas there are controlled conditions in laboratory studies. For this reason, existing procedures probably overestimate the adverse effects of a particular pollutant but may not take into account all of the factors operating at a fill site (Waldichuk, 1973). A dilution bioassay as developed by Plumb (1976) may be more realistic than the use of a single concentration of a pollutant; mixing zone considerations should be used where applicable.

254. In summary, the bioassay test has many limitations, and extrapolation of test information for impact prediction must be carefully considered.

Extensive information on bioassay tests conducted on fill material is unavailable. Research is needed to establish appropriate test conditions and develop information on the reliability of the results.

PART IV: ASSESSMENT OF PROBLEMS AND NEEDS

255. This part is addressed to the second major task of this study: the assessment of problems and needs. Key activities during this task consisted of two visits to WES, weekly meetings of the 12-person research team at the University of Oklahoma, and the conduction of a workshop in Dallas, Texas, on January 20-21, 1977.

256. Assessment of the problems and needs was basically accomplished by a two-step procedure which consisted of (1) identifying various problems and needs in the administrative/procedural and technical areas and (2) establishing priorities of these identified needs through the use of a weighted-rankings technique. The problems and needs were primarily identified through the accomplishment of the basic information gathering task. Part III and Appendices A through G provide detailed descriptions of the literature review, informational contacts, and associated activities. This part contains a description of the weighted-rankings technique, and a delineation of the identified problems and needs and the resultant priorities which were accomplished.

Weighted-Rankings Technique

257. In order to establish priorities for the administrative/procedural and technical problems, the weighted-rankings technique was utilized (Dean and Nishry, 1965). This method is useful for priority establishment, in order of importance, for a series of factors. Table 19 presents an example of the use of the technique. The approach consists of listing a series of factors for ranking, including a dummy factor which is arbitrarily defined as the least important factor in every comparison. The second step is to consider each factor relative to every other factor and assign importance values on the basis that the most important of each pair of factors is given a value of 1.0 and the least important a value of 0. Group discussions should be used to accomplish these decisions, and several iterations may be required in order to reach consensus agreement. If two factors are considered to be of equal importance, each of the pair should be assigned a value of 0.5.

258. Two checkpoints, from a mathematical standpoint, are provided in the method. The sum column should total to be equal to $n(n - 1)/2$, where n is the number of factors being considered. The factor importance coefficient (FIC) column, which is developed by dividing the sum value for each factor by the sum for all factors, should total 1.00. In this example shown in Table 19, the FIC's indicate Factor C to be the most important, followed by Factor A, and then Factor B.

Table 19. Example of weighted-rankings technique

Problem

Establish priorities, in order of importance, of factors (could be 10-15 information gaps each in the administrative/procedural or technical area). For this example, consider factors A, B, C, and Dummy (defined at least important in every comparison).

Procedure

Develop factor importance coefficients by groups decisions on combinations of pairs above. Assign 1.0 to most important, 0.0 to least; 0.5 to each if of equal importance. Group discussions could be used for decisions.

Factor	Assignments						Sum*	Factor Importance Coefficient**
A	1	0	1				2	0.33
B	0			0	1		1	0.17
C		1		1		1	3	0.50
Dummy			0		0	0	0	0
							6	1.00

* Sum should equal $\frac{n(n-1)}{2}$

**Factor Importance Coefficient = $\frac{\text{sum value for each factor}}{\text{sum for all factors}}$

Identification of Administrative/Procedural Problems and Needs

259. Following contacts with the Corps of Engineers, other Federal agencies, and the water resources agency in each state (Appendix C), as well as reviewing Appendices A and B and considerable discussion at the workshop, the listing of administrative/procedural concerns shown in Table 20 was developed. No priorities are implied by the order of concerns in Table 20. The general categories of problems and needs include those associated with institutional relationships (external to the Corps of Engineers), internal relationships (internal to the Corps of Engineers), compliance with Section 404 requirements, rationale for permit issuance (particularly focused on the questions of issuance of general permits and methods for expediting the overall permitting procedure), resource requirements (personnel requirements, monetary resources, and laboratory capabilities), and continuing operational considerations which result from court decisions and changing policies and regulations.

Establishment of Priorities of Administrative/Procedural Problems and Needs

260. The administrative/procedural problems and needs delineated in Table 20 were subjected to the weighted-rankings technique. The results of the assignments of values are given in Table 21. The priorities are suggestive of the major administrative/procedural needs and could be utilized as the basis for the development of research efforts. The area of need considered to be of greatest importance was the rationale for permit issuance, followed by resource requirements and internal Corps relationships.

Identification and Establishment of Priorities of Technical Problems and Needs

261. Technical problems and needs were identified as a result of the contacts with Corps of Engineers, as well as the literature review and associated activities conducted on the physical, chemical, and biological impacts resulting from discharge of fill material (Part III and Appendices C,D,E,F, and G). The key concerns identified from these activities are delineated in Table 22. These technical problems and needs were also subjected to the weighted-rankings technique. The results of the assignments of values are shown in Table 23. These priorities could also be used as the basis for the development of research

Table 20 . Administrative/procedural problems relative to fill material discharge

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A. Institutional Relationships (External to the Corps of Engineers)

   1. Initial information communication and coordination

      a. Corps to States

      b. Corps to other Federal agencies

   2. Continuing communication and coordination

B. Internal Relationships (Corps of Engineers)

   1. Permits program in the administrative structure of the Corps

   2. Problem appreciation and training; environmental activities as part of legitimate personnel reward structure; and commitment of personnel

   3. Dissemination of information to Divisions/Districts and between Divisions/Districts/OCE

C. Compliance with Sec. 404 Requirements

   1. Enforcement

   2. Surveillance, initial (inspection) and continuing efforts

   3. Verification of predicted impacts

D. Rationale for Permit Issuance

   1. Regionally oriented criteria for sorting permit applications into general, individual, and those allowed by regulation

   2. Expediting general and individual permit applications (minor projects)

E. Resource Requirements

   1. Personnel

   2. Laboratory facilities and equipment for Sec. 404 administration

   3. Laboratory certification and quality control of testing

F. Continuing Operational Considerations

   1. Overlapping of old and new laws/regulations with Sec. 404

   2. Dissemination of pertinent information from court decisions

   3. Regulation of long-term uses of filled areas

Table 21 . Weighted rankings of administrative/procedural problems and needs

	Factor	Assignments																					Sum	FIC
A	Institutional Relationships (external to Corps)	0	1	0	0	1	1																3	0.14
B	Internal Relationships (Corps)	1						1	0	0	1	1											4	0.19
C	Compliance with Sec. 404 Requirements		0					0					0	0	1	1							2	0.09
D	Rationale for Permit Issue			1					1				1				1	1	1				6	0.29
E	Resource Requirements				1					1				1			0			1	1		5	0.24
F	Continuing Operational Considerations					0					0				0			0		0		1	1	0.05
Dummy							0					0				0			0		0	0	0	–
																							21	1.00

Table 22 . Technical problems and needs relative to fill material discharge

A. Problem Magnitude

Definitive study on the current magnitude of fill discharge operations, the uses of filled areas, and the types of fill materials involved. This also needs to be projected into the future to achieve a more specific delineation of problem magnitude.

B. Definitions and Characterization

1. Define wetlands boundaries; assemble information on wetlands identification, classification, function, and behavior.

2. Information on the characterization of fill material. Some information is available on selected physical, chemical, and engineering properties of fill materials; however, this information is not complete.

C. Basic Chemical Systems

1. Relative roles of pH, redox potentials, hydrated oxide surfaces, and sulfide formation in the transfer of trace metals from fill material to water and vice versa.

2. Rates of redox reactions at the water/sediment interface; kinetics of manganese and iron oxidation/reduction in the aqueous environment.

3. Qualitative and quantitative information on ion-exchange reactions, sorption/desorption reactions, and complex formation in aquatic systems.

4. Nature and behavior of water/solid interface as related to interstitial water. Relation of interstitial water and bulk water.

D. Basic Biological Systems

1. Effects of toxic materials at all levels in the food chain, on a variety of habitats, and at various stages in the life history of at least the commercially important species.

2. Precise evaluation of biological magnification of heavy metals, pesticides, organic chemicals, and inorganic chemicals at each level in the food chain.

E. Application of Dredged Material Information

1. Applicability of impact evaluation techniques developed (or in process of being developed) for dredging to fill discharge situations. For example, the relevance and applicability of the bulk sediment and elutriate tests; the effect of particle-size distribution on the interpretation of Elutriate Test results and in the environmental impact of fill discharge operations; and the applicability of bioassay test results in the discharge of fill material.

2. Relationships between results from the bulk sediment, elutriate, and bioassay tests and actual impacts in the field.

F. Construction for Impact Minimization

1. Information on the response of various materials once they are in place in the fill. For example, studies are needed on whether or not the properties remain the same upon movement of material and redistri-

Table 22 (Continued)

F. (Continued)

bution. Property changes may occur as a result of sorting, aggregation or dispersion, and liquification.

2. Information on consolidation of fill material, including load-settlement-time relationships, refinement of proposed mathematical model, slurry consolidometer and its applicability to fill material, predictions of long-term settlement, and pore-pressure variations.
3. Innovative methods for increasing the bearing capacity of soft fills.
4. Feasibility of using permeable embankments for impact minimization.
5. Methods for determining the relationship between in situ material to be dredged and final fill properties. Study possibility of making improvements in dredging methods in order to produce a cleaner and more controlled fill material. Study feasibility of separation of dredged material into fractions so that valuable materials (e.g., sand and gravel) can be sorted and recovered.

G. Impact Prediction and Assessment

1. Information on pollution loads from specific types of fill discharge operations and on methods of estimating such loads. Ultimately this includes chemical characterization of fill material, magnitude of discharge operations, and movement of various chemical species from solid to aqueous phases and vice versa.
2. Information on the biological effects of organic fill material, fly ash used as fill material, and solid wastes used as fill material.
3. Information on impact prediction techniques. Physical and mathematical modeling (including bioassay, microcosm, and simulated ecosystem) studies are needed.
4. Information on the movement of metals and nutrients in wetland areas, including bottom areas that are alternately dry and wet.
5. Information on long-term chemical and biological effects resulting from fill material discharge. Most effects are related to the short term (first few years after placement); however, little attention is given to longer term implications. Data are needed that will allow careful distinction between the direct and immediate effects which take place during the construction process itself and the effects which occur during the period of stabilization following completion of the construction.
6. Information on the socio-economic impacts of fill material discharge.

H. Verification of Predicted Impacts

1. Information on after-the-fact verification and documentation of predicted impacts. For example, data are lacking on the water-quality effects of in-water construction, such as the placement of piers, docks, marinas, bulkheads, and pipes.
2. Information on the necessary instrumentation and methods for monitoring fills for crack surveillance.

I. Effectiveness of Control/Reuse Measure

1. Information on the effectiveness of out-of-stream pollution control

Table 22 (Concluded)

I. (Continued)

measures such as mulching, tilling, small flood-control dams, dikes, levees, sediment basins and outfall structures, terraces, diversion structures and channels, grassed waterways and outlets, grade stabilizing structures such as chutes, checkdams and drop spillways, serrated side slopes for highway cut sections, filter berms, flexible down drains, flexible erosion control mats, and temporary storage basins.

2. Information on the potential interaction of fill leachates with building materials such as asphalt or concrete.

Table 23 · Weighted-rankings of technical problems and needs

	Factor	Assignments																																												Sum	FIC
A	Problem Magnitude	0	0	0	0	0	0	0	0	1																																						1	0.02
B	Definitions and Characterization	1									0	0	1	0	0	0		1																														3	0.07
C	Basic Chemical Systems		1								1								0.5	1	0	0	0	0	1																							4.5	0.10
D	Basic Biological Systems			1								1							0.5							1	0	0	0	0	1																	4.5	0.10
E	Application of Dredged Material Information				1								0							0						0						0	0	0	0	1												2	0.04
F	Construction for Impact Minimization					1								1							1						1					1					0	1	1	1								8	0.18
G	Impact Prediction and Assessment						1								1							1						1					1				1				1	1	1	1				9	0.20
H	Verification of Predicted Impacts							1								1							1						1					1				0			0				0	1		6	0.13
I	Effectiveness of Control/ Reuse Measure								1															1						1					1				0			0			1		1	7	0.16
Dummy										0								0							0						0					0				0			0	0		0	0	0	0
																																																45	1.00

efforts. The area of need considered to be of greatest importance was impact prediction and assessment, followed by construction for impact minimization and effectiveness of control/reuse measures.

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APPENDIX A: LEGAL AND LEGISLATIVE HISTORY RELATED TO CORPS DREDGING

When the Constitution was ratified, the Federal Government was granted authority to regulate commerce upon the Nations's waterways. In 1824, Chief Justice Marshall (in Gibbons vs. Ogden 9 Wheaton US 1) extended this authority to include navigation.

As America grew, Federal agencies became aware that they were unable to prevent the placement of man-made obstructions within the nation's waters (Willamette Iron Bridge Com vs. Hatch 1887, 125US1). For this reason, Congress included Sec. 10 within the 1890 River and Harbor Act, prohibiting such unauthorized obstructions. Unfortunately, the bill was inadequate and lacked firm administration. In U.S. vs. Bellingham Bay Boom Com (1899, 176US211), the Supreme Court stated "...creation of any obstruction non affirmatively authorized by law..." was valid if it was authorized by a state law. Urged by Judge G. Koonce, Secs. 9-20 were added to the River and Harbor Act of 1899. This bill made it unlawful to excavate, fill, alter, or modify"... any navigable water of the United States unless recommended by the Chief of Engineers and authorized by the Secretary of War." In principle, every river modification had to be submitted to a District Engineer who determined whether the project created an obstruction. Upon his advice, the project could be approved by the Secretary of War. The dredging or filling of navigable waters (without a permit) was prohibited by Sec. 10 while the unlawful discharge of waste or refuse into them was prohibited by Sec. 13.

In 1958, Congress passed the Fish and Wildlife Coordination Act. In addition to defining wildlife, it attempted to prevent the disturbance or destruction of aquatic nursery and feeding areas caused by dredging or fill activities. It required consultation with applicable state agencies and with the U.S. Fish and Wildlife Service before approving alterations subject to Federal permits. Prior to this act, the Corps' permit requirements had emphasized effects to navigation. Such a policy was upheld in Miami Beach Jockey Club, Inc. vs. Dern (1936, 86F2d 135). The court stated that Sec. 10 permit decisions had to be based exclusively upon whether present conditions would result in obstructions to the water's navigability.

In 1969, the National Environmental Policy Act (NEPA) was passed. This significant act required that prior to approving any project which might significantly affect the quality of the human environment, the responsible agency must prepare a detailed account of (1) the environmental impact, (2) unavoidable adverse effects, (3) alternatives, (4) the relationship between local short-term uses and the enhancement of long-term productivity, and (5) irreversible and irretrievable commitments of resources. In addition, the effects of related secondary activities and the project's importance (to the overall development of the area) had to be considered. By 1971, the courts held that Corps permits could be denied if damage might occur to a region, particularly in the marine environment (Zabel vs. Tabb - 401US910, 91 S. Ct. 873, 27 L. Ed. 2d 808).

Faced with these additional factors, peripheral wetlands (previously satisfactory) were removed as disposal sites. Dredgers turned their attention toward upland areas, transferring the problem from the aquatic to the land environment.

Earlier, in 1948, the Federal Water Pollution and Control Act (FWPCA) attempted to control pollution, in part, by shifting responsibilities toward the states. By 1972, Congress had recognized many errors and had added several amendments (including PL 92-500). Authority was broadened, and states were allowed to substitute their own permits for those previously required by the EPA. Such state permit programs had to define acceptable effluent and water-quality standards and be approved by the EPA.

Secs. 301 and 402 of the FWPCA Amendments of 1972 (PL 92-500) established a National Pollutant Discharge Elimination System (NPDES). The NPDES prohibits, without an EPA permit, the discharge of pollutants into the "waters of the United States." According to the 1972 amendments, both the Corps' refuse and the NPDES permit programs were transferred to either the EPA or to the individual states. Sec. 404 exempted dredged and fill material from the NPDES program. Exclusive Federal regulation of dredged and fill material is controlled by the Secretary of the Army, acting through the Chief of Engineers. He may approve, following notice and public hearing, any discharge of dredged or fill material which enters the Nation's navigable waters. A similar provision within Sec. 103 of the Marine Protection, Research, and Sanctuaries Act (PL 92-532) allows the disposal of dredged material into ocean waters. No provision was made to transfer dredged or fill material disposal authority to the individual states. Congress apparently wanted to avoid the creation of a burdensome bureaucracy and any unreasonable restriction to interstate or foreign commerce which might result from the vigorous enforcement of dredged/fill material disposal by state water-quality programs.

Since the FWPCA dealt with the "waters of the United States," a question arose --- how extensive is the Army's jurisdiction? During the drafting of PL 92-500, the EPA suggested a broad interpretation (similar to their NPDES permit regulations) which included all waters affecting interstate commerce (rather than limiting it to traditional waters which directly support commerce). Sec. 402, however, under which the NPDES program operates, deals primarily with maintaining adequate water quality and overlooks the effects to wildlife and navigation or the destruction of wetlands.

The Corps ultimately restricted its jurisdiction to those waters historically termed "navigable," basing much of their decision upon the legislative history of the FWPCA. Cost was an additional factor. A preliminary study estimated that an additional 1700 jobs and $50 million would be required to expand the permit authority beyond the traditional definition. Additionally, the Corps felt that any discharge of dredged material, sand, or dirt into those waters not classified as navigable could be prosecuted by the EPA under Sec 402.

In April 1974, the Department of the Army published regulations on permit applications and processing as required under Sec. 404 of PL 92-500 and Sec. 103 of PL 92-532. A controversy soon developed between the Corps and the EPA regarding these regulations and how they were affected by U.S. vs. Holland 373 F. Supp. 665 (M.D. Fla. 1974). This case held that the traditional mean high water line (MHWL)[1] does not restrict Federal authority of higher regions if they are periodically inundated by tidal waters.[2] It further stated "... the Commerce clause gives Congress ample authority to reach activities above the (MHWL) that pollute the waters of the U.S." Thus, unauthorized discharges of sand or dredged material onto such areas violates Sec. 301 of PL 92-500.

The Natural Resources Defense Council (NRDC) and the National Wildlife Federation quickly filed suit against the Secretary of the Army (NRDC vs. Callaway, 392 F. Supp. 685 (D.D.C. 1975), hoping to force a redefinition of navigable waters and to expand the Corps' authority. A district court agreed and in March 1975 ordered the Army to immediately re-issue guidelines which included all waters of the United States.

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1 This line on shore is the average of all high tides (or higher high tides on the Pacific Coast) averaged over 18.6 yr.

2 In March 1976, the Corps' tidal jurisdiction was ruled to extend beyond dikes up to "the former lines of (MHWL) in its unobstructed natural state" provided the dike has not become improved solid upland-Leslie Salt Com vs. R. F. Froehlke (U.S.D.C., N.D. Ca., Civ. No. 73-1194).

In May 1975, the Corps published four alternatives for responding to the district court order. Alternatives two and four were limited and included jurisdiction over primary tributaries and all coastal regions that support saltwater vegetation. The other two alternatives (patterned after the EPA program) were broader and would double the tidal shoreline and increase the Corps' shoreline jurisdiction from 50,000 miles to well over two million miles. Alternative one was supported by a majority of the Corps' critics, including the EPA, who claimed it would do the best job of protecting wetlands. The Corps favored alternative four. Rather than including virtually all coastal and inland waters, alternative four included waters up to either (1) the MHWL (including those areas periodically inundated that support aquatic vegetation) or (2) the saltwater vegetation line.

Upon issuing the four alternatives, ten environmental groups (headed by the NRDC) accused the Corps of launching a nationwide scare campaign. They believed the Corps was seeking to avoid its responsibilities by inciting a backlash among uninformed citizens. Russell Train, Administrator of EPA, said the proposals were recklessly issued and were being misunderstood by farmers.

A majority of letters submitted to Federal agencies expressed opposition to any of the alternatives, claiming they would infringe upon states' rights or restrict agriculture and forest activities. Although permits are required for the damming or filling of major rivers, a significant concern involved the construction of logging roads. Such action required numerous fills along streambeds. If permits were required for each location, the administrative burden and delay could seriously damage the economics of timber interests. The Corps considered two possible solutions: the road construction might be viewed as a normal harvesting activity and not subject to regulation, or regional general permits could be issued for clearly described activities (similar in nature and which individually do not adversely affect the environment). The U.S. Department of Agriculture questioned whether these alternatives were at odds with pending land-use legislation.

In July 1975, both the EPA and the Corps testified before the House's Public Works Subcommittee on Water Resources. Attempting to calm citizen and Subcommittee fears, Victor Veysey (Assistant Secretary to the Army for Civil Works) pointed out that the proposed regulations were tentative and attempted to simplify the permit program. He unveiled a three-phased program to expand the Corps' authority:

Phase I - effective 25 July 1975, extend authority to contiguous adjacent wetlands.

Phase II - effective 1 July 1976, extend authority to primary tributaries and natural lakes larger than five acres and to their adjacent wetlands.

Phase III- effective 1 July 1977, extend authority to the headwaters with flow greater than five cubic feet per second.

This phased expansion, the Corps hoped, would allow Congress time to consider pending amendments, including the transferral of dredging permit authority to the states.

Because Sec. 402 of PL 92-500 granted states (with EPA-approved programs) the authority to issue their own permits, a question arose whether Federal agencies required such permits. A test case (Minnesota vs. Callaway, U.S.D.C., D. Minn. 3rd Div., 3-75-Civ.-120) involved Minnesota's program. State regulation WPC 36e(6) requires a state permit whenever an individual disposes of material. Minnesota claimed that sediment removed (without a state permit) from the Mississippi River, Lake Superior, and the Lake of the Woods caused the resuspension of pollutants, violating their regulations WPC 15(c)(3) and WPC 15(c)(6). The court ruled originally that Minnesota could regulate dredging activities and require the Corps to obtain a permit. The Corps successfully appealed (Minnesota vs. Hoffman, U.S.C.A. 8th Circuit 75-1869), contending that Sec. 313 of PL 92-500 does not require such permits (affirmed by the Supreme Court in EPA vs. California, 44 U.S.L.W. 4781 June 1976). It noted that Sec. 313 provides that Federal agencies "...shall comply with...state...requirements respecting control...of pollution...for securing discharge permits which state regulatory bodies may impose on local discharges under Sec. 402." A lower court held that a difference exists between compliance with a "requirement" and a state "standard."

The Army argued that, taken as a whole, Congress did not intend to subject Corps dredging activity (which maintains navigation) to state permit laws. They pointed out that Sec. 404(a) grants the Corps exclusive right to "...issue permits...for the disposal of dredged or fill material at specified disposal sites." Such permits are subject only to EPA guidelines specified in Sec. 403(c).

EPA's authority is granted in Sec. 402, not Sec. 404 (except for supplying guidelines and vetoing projects which create unacceptable water quality). Since Sec. 402 grants dual authority to the EPA and the states, the Army concluded that states have no authority greater than EPA. Sec. 402(a)(1) says, "Except as provided in Sec. 318 and 404 of this act, the (EPA) Administrator may...issue a permit for the discharge of any pollutant." Thus, neither the states nor the EPA can regulate Sec. 404 activities which involve pollutants described in Sec. 402(b). States do have some authority under Sec. 401(c), but Sec. 401(a)(6) specifically exempts Federal agencies dealing with Sec. 401 issues from permit requirements.

Taking Secs. 401, 402, and 404 collectively, the Corps contended that state regulation is limited to individual discharges and does not apply to the Corps. The court found that Congress had not intended to permit states to regulate the Corps' dredging activities.

Although previous cases granted the Corps regulatory authority over navigable waters, defining when and if they are navigable has been difficult. If a waterbody can transport commerce, legally it is navigable. The Supreme Court has included all waters which previously, presently, or potentially possess commercial value. Once defined, this definition applies to the entire surface, continues even if later action reduces its navigability, and can be altered only by Congress. Similarly, "A waterway, otherwise suitable for navigation is not barred from that classification merely because artificial aids must make the highway suitable for...commercial navigation" (U.S. vs. Appalachian Electric Power Company 1940, 311US377). This last case granted Federal agencies the power to license private hydroelectric projects and subject their waters to regulation.

Many of the Corps' other legal problems are similar. U.S. vs. Kaiser Aetna (U.S.D.C., D. Hawaii, No. 73-3864) involved dredging improvements to the Hawaii Kai marina (a privately owned area transformed into a navigable harbor capable of conducting interstate commerce). Many footnotes within that case cited previous determinations of navigability. Similarly the courts found historic and commercial use a reason to declare the Little River navigable (U.S. vs. Joint Allen, Hunting, Wells, and Whittey County Drainage Board Civ. No. F. 75-52). Unfortunately, it failed to rule whether dredged material was subject to restrictions specified within Secs. 301 and 404 of PL 92-500.

Scenic Hudson Preservation Conference vs. Callaway (U.S.D.C., S.D.N.Y., 73-Civ.-4276) dealt with another private power company, Consolidated Edison (ConEd), which attempted to construct the Storm King hydroelectric plant without first obtaining permits as required by the River and Harbor Act and PL 92-500. The court, responding to the environmentalists' suit, pointed out that the Federal Power Commission (FPC) had properly licensed the ConEd facility and that no Sec. 10 permit was required. This FPC control does not, however, preclude compliance with Sec. 404. ConEd was ordered to conform before discharging any dredged or fill material into the Hudson River.

In October 1976, the FPC proposed regulations which would allow the Corps to evaluate the effects of hydroelectric projects and associated discharges of dredged or fill material.

The extent to which the Corps' authority extended was argued in U.S. vs. Sexton Cove Estates, Inc. (U.S.D.C., S.D. Fla., No. 1389 F. Supp. 602). In 1969, Sexton began dredging two canals on private land for its Florida development. They were initially advised that no permit was required if their activities were shoreward of a mangrove fringe. But during an inspection in 1971, the Corps determined that a permit was needed. Sexton filed for an after-the-fact permit that was denied following 19 months of review. Seeking to overturn this judgment, Sexton argued that the law made no mention of the MHWL and that the Corps had arbitrarily adopted this jurisdiction. The Fifth Circuit Court ruled, however, that the Corps' jurisdiction was proper and based upon historic factors. It ordered Sexton to cease their dredging and to refill five canals directly connected to the Blackwater Sound. Five other landlocked canals were ruled beyond the Corps' jurisdiction.

A similar judgment was rendered in Fred Weiszmann vs. Corps of Engineers (U.S.C.A., 5th Circuit, 562 F. 2nd 1302). The same circuit court fined Weiszman $5000 because he had connected a canal, located above a MHWL, to a pre-existing upland canal. The court ruled that dredged sediment from one canal had polluted a navigable pre-existing canal.

Coastal wetlands are under Sec. 404 jurisdiction and are defined as areas periodically inundated by saline or brackish waters and characterized by brackish water vegetation (Black, 1976). Unfortunately, such a definition fails to define the frequency of such inundation. Environmental groups once again counseled the Corps to accept a more inclusive definition which would remove the word "periodically." Thus, wetlands not physically connected but within close proximity to coastal waters could be regulated.

Some court cases have arisen because the Corps failed to hold public hearings as required by Sec. 404. River Defense Committee vs. Callaway (U.S.D.C., S.D.N.Y., 74-Civ.-159) resulted when the Corps allowed the construction of a bulkhead at Grandview-on-Hudson without first holding public hearings or requiring an environmental impact statement that described the cumulative effects of fill material. The district court ordered the Corps to comply with these NEPA and PL 92-500 requirements. Similarly, in Save Crystal Beach Assoc. vs. Callaway (U.S.D.C., M.D. Fla., No. 74-459c, Civ.-T-H), the Corps was enjoined from filling St. Joseph Sound with dredged material because no environmental impact statement was presented which described alternatives. The court observed that the project would permanently affect area beaches and that additional disposal sites would be required. The Corps admitted that an alternative site had been studied, but that it was rejected because litigation arose which involved the site's owner.

One case (NRDC vs. Callaway, U.S.D.C., Conn., No. H-74-268) seemed to include all previous difficulties. Environmental groups brought suit against the Secretaries of the Army and Navy to prevent dumping of highly polluted dredged material into the New London site located within Long Island Sound. The plaintiffs charged that bottom currents break up and disperse the sludge northwestward, destroying marine resources. The Army was cited for violating Sec. 404(b) by failing to follow EPA guidelines. The Navy was charged with ignoring alternative sites which avoided cumulative problems associated with similar dumpings by General Dynamics and the Coast Guard. The Navy admitted that an alternative site at Brenton Reef had been studied but claimed the Army failed to evaluate the risks involved at the New London site; consequently, they were ordered to restudy the issue (especially the cumulative impacts). The court urged the Navy to consider other disposal methods, such as the containment islands used by the Natural Marine Fisheries Service in the Great Lakes. Following an appeal to the district court, the Corps was ordered to suspend the Navy's permit at the New London site.

Based upon such trying experiences, Sen. Hart (D-CO) said, "The Corps of Engineers, through the lack of clear Congressional mandate, has floundered through the regulatory wilderness under Sec. 404 and has become understandably court-shy."[3]

Attempting to clearly define the term "navigable waters," the 94th Congress proposed several bills. HR 7690 (introduced by Rep. Cochran, R-MI and Rep. Breaux, D-LA) and S 1878 (introduced by Sen. Tower, R-TX) would have amended Sec. 404 of PL 92-500 by redefining navigable water in the more traditional sense as "...all waters which are presently used...as a means to transporting interstate commerce shoreward to their ordinary highwater mark, including all which are subject to the ebb and flow of the tide shoreward to their mean high water mark." It would essentially reverse those court decisions which extended the Corps authority well beyond this mark. HR 7441

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[3] Senate floor July 2, 1976 from Environmental Reporter (p. 436, 1976).

(introduced by Rep. Long, D-LA) was even more restrictive. It would have, in addition to redefining navigable waters, limited Corps authority to only those dredged or fill discharges granted by Sec. 404. S 1796 (introduced by Sen. Buckley, Conservative-NY) and S 1843 (by Sen. Dole, R-KS) would have waived the Corps' requirement to issue permits, provided that qualified states possessed a similar regulatory program.

The bill which eventually passed the House in June 1976, was HR 9560. It contained an amendment, offered by Rep. Wright (D-TX), similar to HR 7690, which redefined "navigable waters" to include coastal wetlands. Further, it expanded qualified state permit programs to include dredged and fill material. Finally, it established joint programs between the Corps and individual states to identify wetlands areas. This last provision was endorsed by Russell Train, Administrator of EPA, who felt America's wetlands were gradually being eliminated from PL 92-500 authority and that their loss might upset the hydrologic cycle. Environmental groups, such as the NRDC, claimed that HR 9560 still left too many wetlands unprotected.

Other groups were upset because amendments offered by Reps. Cleveland (R-NH) and Harsha (R-OH) were rejected. These would have exempted, from Secs. 402 and 404 control, farm and ranch activities and fill material used to maintain serviceable dikes, dams, and groins. Rep. Harsha expressed his opposition to the Wright amendment, claiming that it basically contained provisions of the Breaux amendment and that it presented only a "...meat-ax approach (to allay fears) of overregulation and overinvolvement of the Federal Government."[4]

HR 9560 also contained an amendment by Rep. Levitas (D-GA) which allowed Congress 60 days to review, evaluate, and approve new Federal agencies' regulations. Levitas hoped to correct the problem that"...(Administrative rules) are passed by an unelected bureaucracy not responsive to the public."[5] Sen. Muskie (D-ME) agreed, but suggested that needless government interference could best be reduced by eliminating Sec. 404. He proposed granting to either the EPA or the states the authority to regulate dredged and fill material. Russell Train pointed out, however, that states differ substantially in their programs.

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4 p. 222, 1976, Environmental Reporter.

5 Ibid.

The administrative branch proposed its own legislation (drafted by the Departments of Agriculture, Commerce, Justice, and Interior). It would have expanded Sec. 404 by 13 subsections while reducing administrative duplication. This legislation was more restrictive than HR 9560 in limiting Corps authority to those projects affecting navigation, water quality, and fish and wildlife.

The Corps' Phase II program was to have been initiated on 1 July 1976. The Senate, wishing to study proposed Sec. 404 amendments, convinced President Ford to suspend it for 60 days. This action placed the Corps in opposition to NRDC vs. Callaway (392 F. Supp. 685 D.D.C. 1975), and an attorney for the NRDC noted that court orders granted no extensions. An Indiana district court ruled in August 1976 (U.S. vs. Byrd U.S.D.C., N.D. Ind., No. 576-109) that the Corps still had authority to halt discharges which might seriously affect water quality and that it had acted properly to protect the wetlands (a region periodically inundated and supporting aquatic vegetation).

Before the 1976 Labor Day recess, the Senate passed (on voice vote) its amendment (S 2710) to PL 92-500. This bill limited Corps jurisdiction to traditionally defined navigable waters but exempted certain farming, ranching, and mining activities from permit requirements. Sen. Huddleton's (D-KY) floor amendment exempting terracing, the erection of small dikes and dams, and other activities of the Soil Conservation Service was added. Finally, states capable of administering NPDES programs were delegated permit authority. Sen. Tower attempted to include the House-passed Wright amendment, but the amendment was defeated 50 to 39. This exclusion resulted in the Senate bill being rejected by the House during conference committee hearings.

Therefore, no bill was passed by the 94th Congress which provided the Corps a new definition of "navigable water" jurisdiction.

APPENDIX B: REGULATIONS AND GUIDELINES RELATING TO REQUIREMENTS FOR FILL DISCHARGE

Section 404 of PL 92-500 authorized the Secretary of the Army, acting through the Chief of Engineers, to issue permits for the discharge of dredged or fill material into navigable waters at specified disposal sites. It also provided that guidelines developed by the EPA be applied by the Corps in selection of disposal sites and in the application review process. Proposed Corps Regulations and EPA Guidelines were published in May 1975. After review of comments received, the Corps issued Interim Final Regulations for Discharge of Dredged and Fill Material in July 1975 (Federal Register, Vol. 40, No. 144, 25 July 1975). In September 1975, the EPA issued its Interim Final Guidelines (Federal Register, Vol. 40, No. 173, 5 September 1975) to be used by the Corps in evaluating proposed discharges of dredged or fill material into navigable waters. This appendix highlights certain features of these Regulations and Guidelines.

Permit application procedures include the steps to be taken by the applicant and the District Engineer. Additional steps or variations in the procedures may be required in specific Corps Districts to facilitate coordination with state and local agencies.

The applicant is to prepare his application, using ENG Form 4345, according to directions furnished in the Corps' pamphlet "Application for Department of the Army Permits for Activities in Waterways." There will be some exceptions to the requirement for the full-scale permit processing procedure. These include general permits, short-form application procedures, and abbreviated processing for certain small-scale bulkhead and fill activities. The general permits are intended for certain clearly described categories of structures or work, and would be authorized only for those activities that are substantially similar in nature, that cause only minimal adverse environmental impact when performed separately, and have only a minimal adverse cumulative effect on the environment.

The time required for processing an application depends on such factors as the size and nature of the activity, the magnitude of the environmental impacts, the number of Federal and state agencies involved, whether or not an EIS must be prepared by the Corps, and the degree of environmental opposition to the project.

The District Engineer is to use the EPA Guidelines in making an ecological evaluation of the proposed discharge to determine whether or not to issue a permit. He is also to evaluate information contained in an environmental impact assessment, environmental statement (if required), and appropriate coastal zone management programs and/or river basin plans.

Where permits are required on a single-case basis, the District Engineer must first consider the necessity for testing. The Elutriate Test may be used to predict the effect on water quality due to release of contaminants from the material in question to the water column. Major constituents in the Elutriate Test to be analyzed are determined by the District Engineer after evaluating comments received from the EPA and considering known sources of discharge in the area and known characteristics of the extraction and disposal sites. Depending on the total concentration of chemical constitutents in the sediment, a total sediment analysis may be required. The District Engineer may also specify use of bioassays, biological community structure studies, and evaluation of biological indicator species. Bioassays may be required if they will be of value for determining such effects as toxicity, stimulation, inhibition, or bio-accumulation. An appropriate benthic bioassay test may be used when it will be of value in assessing ecological effects and in establishing discharge conditions. No single test or approach is applicable in all cases to evaluate the effects of proposed discharges of dredged or fill material.

Information obtained about a proposed operation must be interpreted in terms of the operation's predicted effect on the aquatic environment, including its substrate and margins, the biota inhabiting such areas, and human uses thereof. Particular emphasis is to be given to municipal water supply intakes, shellfish, fisheries, wildlife, recreational activities, threatened or endangered species, benthic life, wetlands, and submerged vegetation. The District is to consider the economic cost of performing the evaluation, the utility of the data to be provided, and the nature and magnitude of any potential environmental effect.

Unless the District Engineer determines otherwise, dredged or fill material may be excluded from the evaluation procedures if, for example, the material is

(1) A naturally occurring sedimentary material (sand or gravel) with particle sizes larger than silt.

(2) Intended for beach nourishment or restoration.

(3) Substantially the same as the substrate at the proposed disposal site.

In evaluating whether to permit a proposed discharge, consideration is to be given to the need for the proposed activity, the availability of alternate sites and methods of disposal that are less damaging to the environment, and water quality standards as are appropriate and applicable. Specific constraints to be considered in the evaluation are

(1) Avoid discharge activities that will

a. Significantly disrupt the chemical, physical, or biological integrity of the aquatic ecosystem, of which aquatic biota, substrate, and the normal fluctuations of water level are integral components.

b. Significantly disrupt the food chain including alterations or decrease in diversity of plant and animal species.

c. Inhibit the movement of fauna, especially their movement into and out of feeding, spawning, breeding, and nursery areas.

d. Destroy wetland areas having significant functions in maintenance of water quality.

e. Degrade water quality.

(2) Minimize discharge activities that will

a. Degrade esthetic, recreational, and economic values.

b. Cause intolerable turbidity levels.

c. Destroy or isolate areas that serve the function of retaining natural high waters or flood waters.

The EPA Guidelines require that consideration be given to preventing degradation of existing water uses at proposed disposal sites. Pertinent considerations can be grouped into two categories: prohibitory and precautionary. In the former category, no disposal site may be designated nor a discharge allowed that will adversely affect a public water supply intake or concentrations of shellfish, or will jeopardize the continued existence of threatened or endangered species. In the latter category, the precautions are that in designating a disposal site or allowing a discharge, the District Engineer avoid significant disruption of and/or minimize impact on marine or aquatic sanctuaries; areas of dispersed shellfish populations; wildlife habitat, food chains, and community structures; areas of submerged vegetation or significant biological productivity; wetlands; and recreational areas.

After areas have been tentatively designated as disposal sites, the District Engineer may review them to assess the cumulative effects of existing and proposed disposal activities in those areas. He will consult the appropriate regional director of the EPA, the Fish and Wildlife Service, the National Marine Fisheries Service, and the Soil Conservation Service, as well as appropriate state agencies.

The specified disposal site should be confined to the smallest practicable area consistent with the type of dispersion determined to be appropriate under the EPA Guidelines. According to the Guidelines, the mixing zone is the smallest practicable zone within each specified disposal site in which desired concentrations of constituents must be achieved. In determining the acceptability of a proposed mixing zone, the District Engineer and the EPA's Regional Administrator will consider

(1) Surface area, shape, and volume of the discharge site.

(2) Current velocity, direction, and consistency at the discharge site.

(3) Degree of turbulence.

(4) Stratification attributable to causes such as salinity, obstructions, and specific gravity.

(5) Any on-site studies or mathematical models that have been developed with respect to mixing patterns at the discharge site.

(6) Other factors prevailing at the discharge site that affect rates and patterns of mixing.

The District Engineer will use a general balancing process in reaching his decision on whether to authorize a given activity and in specifying conditions under which that activity may occur, if authorized. In addition to the anticipated environmental effects of the activity, he must also weight such factors as economics, flood damage prevention, navigation, recreation, and the needs and welfare of the public. The Administrator of EPA can prohibit or restrict use of any defined area as a disposal site if he determines that the discharge of dredged or fill material will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas, or wildlife or recreational areas.

APPENDIX C: INFORMATIONAL CONTACTS

One of the major areas of emphasis in this study was the establishment of contacts with personnel involved in the Section 404 permitting process at the Federal and state levels. Federal contacts included visits and telephone calls to numerous Corps offices as well as to several other Federal agencies having involvement with Section 404. A telephone survey of the water resources agencies in each of the 50 states was also conducted.

The primary purpose of each of these visits/contacts was to identify problems associated with administrative/procedural and technical aspects of Section 404 of PL 92-500. Additional purposes included procurement of technical references/studies pertinent to the discharge of fill material and identification of potential projects which could serve as case studies. Additionally, requests were made for example discharge permit applications (non-Corps), Statements of Findings (Corps), and environmental impact statements dealing with the discharge of fill material.

This appendix summarizes the findings from these contacts, particularly as related to the identification of problems associated with administrative/procedural and technical concerns.

Contacts with the Corps of Engineers and Other Federal Agencies

Fourteen District/Division offices of the Corps of Engineers were visited during September and October, 1976. A visit was also made to the Office of the Chief of Engineers (OCE) in September. Selection of the specific Divisions/Districts to be visited was based on a combination of factors. Basic criteria utilized in this selection were: (1) the Districts/Divisions to be visited should be geographically distributed within the continental United States, including coastal (Atlantic, Gulf of Mexico, and Pacific) and inland locations, as well as the Great Lakes area; and (2) the Districts/Divisions to be visited should have substantial experience in the processing of permit applications for fill material discharge.

In terms of geographic distribution, the final selection consisted of three offices on the Atlantic coast (New York District, Philadelphia District, and Jacksonville District), two locations on the Gulf of Mexico (Mobile District and New Orleans District), three locations on the Pacific coast (San

Francisco District, Portland District, and Seattle District), three inland locations (Fort Worth District, Omaha District, and Missouri River Division), and three Great Lakes locations (Chicago District, North Central Division, and Buffalo District). Contact was also made with the Tulsa District; however, it was determined that there was minimal activity on Sec. 404 permits in this office.

Visits and phone contacts were made with ten other Federal agencies and related organizations: Soil Conservation Service (Chickasha), Geological Survey (Oklahoma City), Bureau of Reclamation (Oklahoma City), Environmental Protection Agency (Dallas), Federal Highway Administration (Fort Worth), Oklahoma State Highway Department (Oklahoma City), Bureau of Land Management (Santa Fe), American Association of State Highway and Transportation Officials (Washington D.C.), Bureau of Mines (Washington, D.C.) and the National Research council (Washington, D.C.). The following criteria were utilized to identify agencies to be contacted: (1) they should be oriented to projects involving the discharge of fill material, and (2) they should have some previous experience with Sec. 404 permits.

The information received from contacts with the Corps of Engineers and the ten other agencies/organizations was assembled into comments related to administrative/procedural concerns, testing of fill material prior to discharge, and technical concerns. This information is summarized below.

Administrative/procedural concerns

1. There is no uniformity in the approach used by Corps District Offices and state agencies relative to permit applications. Some provide forms, others provide very little information.

2. Consideration needs to be given to defining project sizes, project types, and types of fill material for which permits would not be required due to minimal environmental impacts. Much of the administrative work in the Sec. 404 program is directed toward issues of minor environmental concern.

3. Guidance is needed regarding implementation of the concept of general permits. No information is available on when general permits will be acceptable, where they could be applied, nor the criteria which should be used in making a decision to grant a general permit. (A general permit would replace individual permits for multiple projects of similar types.)

4. Consideration needs to be given to the work load required in implementation of the Corps' expanding program on navigable waters. Heavy work loads already exist in many offices.

5. There is need for coordination and information exchange between the

Corps of Engineers and other Federal agencies which are involved directly or indirectly with Sec. 404.

6. There are wide variations in the commitment of Corps personnel to the effective administration of Sec. 404. Many personnel do not have a sense of the problem and potential environmental impacts which can result from the fill material discharge. There is also evidence that the need for an interdisciplinary approach in environmental impact assessment is not recognized.

7. There are apparent overlaps between ocean dumping policies and permitting requirements for fill material discharge. There are questions associated with projects involving beach nourishment (since beach nourishment is included in the definition of fill material) as well as in various criteria associated with ocean dumping.

8. There are continuing difficulties due to the dynamic nature of the Sec. 404 permit program. Numerous court decisions have been rendered and many cases are in progress. The implications of these activities relative to administrative policies need to be quickly disseminated to the District level.

Testing

1. There is minimal guidance provided to permit applicants relative to required testing.

2. There is inconsistency on the application and perceived advantages of elutriate testing. There is also no uniformity between the acceptability of the Elutriate Test results by the Corps of Engineers and the EPA. EPA Regional offices have adopted different viewpoints relative to the Elutriate Test.

3. Even if uniformity in recommended testing and results interpretation could be achieved, little consideration has been given to the availability of facilities/resources for laboratory and field testing.

Technical concerns

1. There is need for a definitive study on the current magnitude of fill discharge operations, the uses of filled areas, and the types of fill materials involved. This also needs to be projected into the future in order to achieve a more specific delineation of problem magnitude.

2. The entire subject of wetlands is a confused issue. The areas of concern include the need to clearly define boundaries, to state the criteria for definition, and to have information on wetlands identification, classification, function, and behavior.

3. There is need for specific information on the characterization of fill material. Some information is available on selected physical, chemical, and engineering properties of fill materials; however, this information is not complete.

4. Even though some information is available on the environmental impacts of certain types of materials, there is little specific information organized by type of fill material and project.

5. There is little information on long-term physical, chemical, and biological effects resulting from fill material discharge. Most effects are related to the short term (first few years after placement).

6. There is essentially no information available on after-the-fact verification and documentation of the occurrence of predicted impacts.

7. There is very little information regarding the socio-economic impacts of fill material discharge. In addition, minimal attention has been focused on potential impacts to the cultural environment, for example, loss of archeological sites.

Telephone Survey of State Water Resources Agencies

A telephone survey of the water resources agency in each of the 50 states was conducted during the fall, 1976. The purpose of the survey was to

1. Determine the participation of each state in the regulation of dredged and fill material at the Federal level (with the U.S. Army Corps of Engineers).

2. Determine the existence and extent of any state laws and programs for the regulation of dredging and filling activities.

3. Determine problems and informational inadequacies in the assessment of the environmental effects of filling activities.

4. Identify various state regulations and permitting applications.

5. Identify studies relating to the environmental impact of fill material.

The telephone survey was conducted by first identifying the responsible agency/program/person in each state. In order to provide consistency in the questions asked and the information requested, a form was completed on each contact. A copy of the form utilized for this purpose is shown as Table C-1. One of the difficulties associated with the telephone survey was the potential for confusion between Sec. 404 permits and the National Pollutant Discharge Elimination System (NPDES) permits. Following compilation of all information from the telephone contacts and subsequent letters and materials as received, summary information for each state was sent back to the individuals contacted and confirmation of the stated information requested.

Table C-1. Form used for conducting state telephone survey

State:________________

Date:____________ Time:______________ Phone No.____________

Person Called:____

Address:

Brief summary of experiences:

Problems with discharge permit applications:

Information available:

/__/ send example discharge permit application (   )

Table C-2 summarizes the results of the survey in relation to whether the individual state had an active Sec. 404 program, whether they rely on the Federal government for this administration, or whether both state and Federal government work together on the program. Of the fifty states contacted, the persons interviewed reported that 29 were active in the regulation of fill material with programs at the state level. The range of participation varied from New Hampshire and Wyoming, which do not have much activity at the Federal level even though they both have an active state regulatory program, to such states as Florida and South Carolina, who are very active with both Federal and state regulatory programs. As can be seen in Figure C-1, the coastal states and those around the Great Lakes (solid green color) are generally active at both the Federal and state levels.

It was found that in thirteen states the regulation of fill material was only through cooperation with the Corps of Engineers administration of Sec. 404 of PL 92-500. In eight states, mostly inland, it was found there was no regulation of fill material at the state level and minimal activity by the Corps of Engineers in the administration of Sec. 404 permits. While at least some of these eight states did not seem to have any filling activity at the present time, the regulation of such activities will probably become important with the implementation of Phase III.

The conclusions from the telephone survey of the fifty states are as follows:

1. Among the 25 states that are active in the certification of U.S. Army Corps of Engineers' discharge permit applications and have a regulatory program of their own, there is some duplication of effort. This occurs mostly in states where the laws and areas of jurisdiction are very similar and there is insufficient coordination with the U.S. Army Corps of Engineers. Communication and cooperation between each U.S. Army Corps of Engineers District and the affected states should be improved and duplication of effort reduced. It is noted that Corps regulations make it possible for the joint processing of permits.
2. The amount of work required at the state and Federal levels to regulate filling activities could be reduced by efforts to make the state laws and administrative procedures similar to the Federal laws and procedures. This would also help to expedite review of applications and shorten the waiting time for the applicant.
3. One area of particular concern is in the definition of and regulation of the filling of wetlands. More coordination with the states is needed to eliminate confusion and duplication of effort.

Table C-2. Summary of results of survey of state water resources agencies

State	Activity, Section 404 Program			
	State Administration Only	Federal Administration Only	Both Federal and State Administration	Neither Federal nor State Administration
Alabama		X		
Alaska				X
Arizona				X
Arkansas		X		
California				X
Colorado		X		
Connecticut			X	
Delaware			X	
Florida			X	
Georgia	X*			
Hawaii		X		
Idaho			X	
Illinois			X	
Indiana			X	
Iowa			X	
Kansas			X	
Kentucky		X		
Louisiana		X		
Maine			X	
Maryland			X	
Massachusetts			X	
Michigan			X	
Minnesota			X	
Mississippi		X		
Missouri		X		
Montana			X	
Nebraska				X
Nevada				X
New Hampshire	X			
New Jersey			X*	
New Mexico		X		
New York			X	
North Carolina			X*	
North Dakota		X		
Ohio				X
Oklahoma	X			
Oregon			X	
Pennsylvania			X	
Rhode Island			X	
South Carolina			X	
South Dakota				X
Tennessee		X		
Texas		X		
Utah				X
Vermont			X	
Virginia			X	
Washington			X	
West Virginia		X		
Winconsin			X	
Wyoming	X			
TOTAL	4	13	25	8

* State regulation primarily in coastal areas.

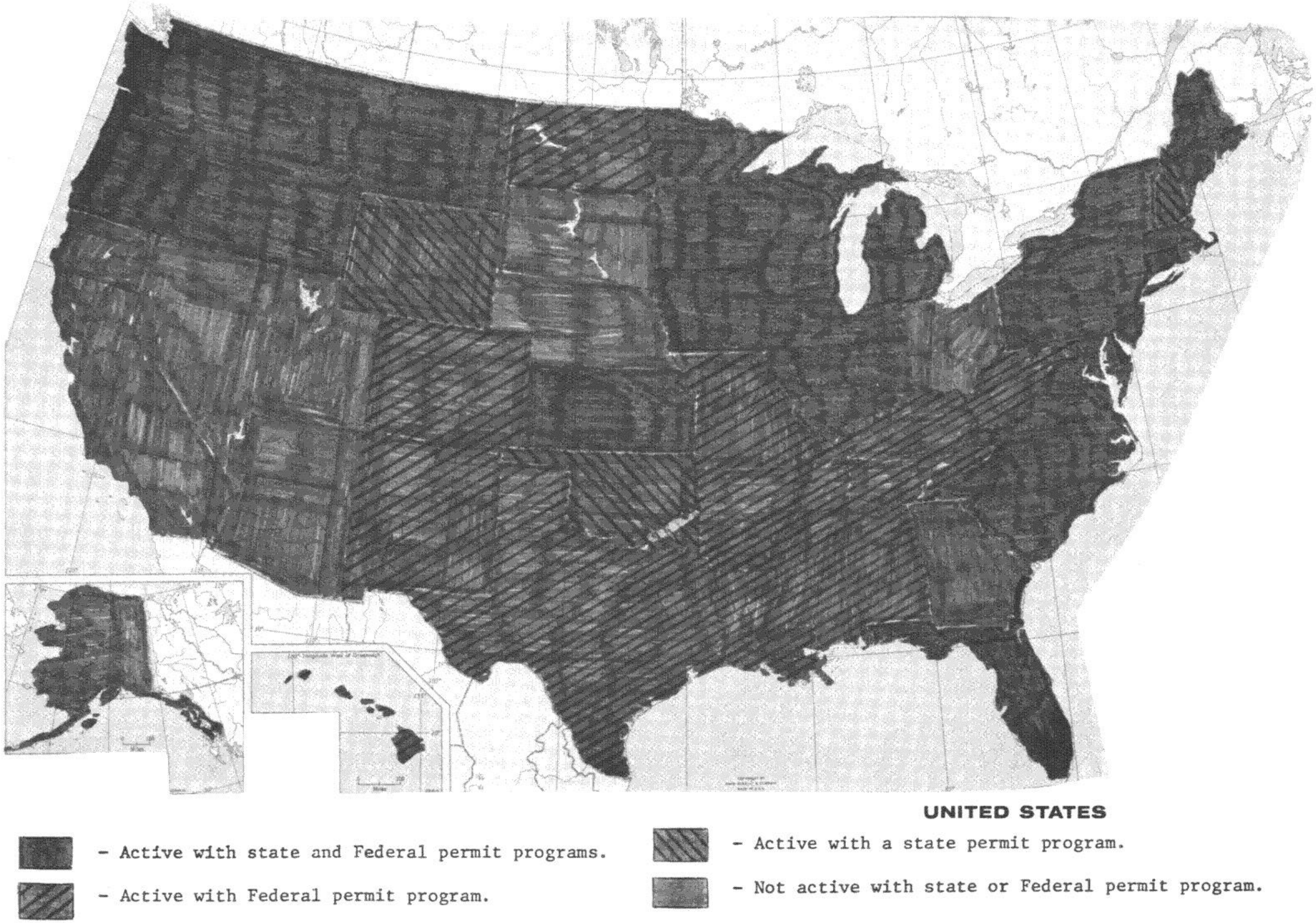

FIGURE C-1: Activity of the States in the Regulation of Fill Material

4. Of the states that only participate in the certification of U.S. Army Corps of Engineers' discharge permit applications, and do not have a regulatory program of their own, it is important that the Federal program be applied evenly and with great care as there is no other protection of the environment against filling activities.

5. In all states there is a limit in the number of personnel available for the regulation of filling activities. More general permits could be issued for minor and small projects so that staffs at both the state and Federal levels could put more effort into the regulation of major or controversial projects.

6. In those states where there are multiple U.S. Army Corps of Engineer Districts (Texas, for example) it would be very helpful if there were more similarity in the administrative procedures of the Districts and uniformity in the enforcement of regulations.

7. The applicant would be helped in all cases if the review process were expedited. Shortening the time for review by other state and Federal agencies and improving communication would facilitate the review process.

A summary of information related to each state program is in Table C-3. Table C-4 tabulates the information required on permit applications for filling activities by 19 of the 25 states with active permit programs.

Table C-3. Summary of state activities in fill material discharge regulation.

Alabama

Alabama participates in the certification of Corps of Engineers Section 404 permits and cooperates by issuing a joint public notice. About 176 applications were completed in 1975 and 153 applications were completed in the first 10 months of 1976. The review process takes about 45-60 days for minor projects. Most applications are certified with no problems, but conditions and limitations are placed on some. Alabama relies heavily on the Corps permit program to regulate filling activity as they do not have a separate state permit program. General permits issued to date include one for small bulkhead or retainer walls and one for bridges and pilings.

Alaska

There is no state permit program in Alaska to regulate fill activity. There have been about 300 permit applications filed with the Corps of Engineers and the state comments on these but they do not certify them. The state is just beginning to draft guidelines for a law to regulate fill activities, and they anticipate being soon involved in the certification of Corps permit applications.

Arizona

There is no Federal or state permit activity for the regulation of fill material. The only possible area for activity would be the Colorado River on which there has been no activity and none is anticipated. The state water-quality standards would regulate all construction in any waterway. There was a recent attempt to pass a state law regulating fill activity but it failed.

Arkansas

Arkansas does not have a law that specifically applies to fill activities, but they do participate in the certification of Corps Section 404 permits. There is presently a shortage of personnel needed to enforce a state-wide permit program to regulate fill activities.

California

While California does not have a specific permitting program for the regulation of fill activities, it does regulate all activities that may violate state water-quality standards, including dredge and fill discharge, by the certification of permits under Sections 401 and 402 of P.L. 92-500. California has separate regional Water Quality Control Boards which have the responsibility of performing field work and setting waste discharge requirements in their region.

Colorado

While Colorado does not have a specific state law regulating the discharge of fill material, these activities are regulated under programs for water-quality certification and certification for construction activities in or near state waters. The state is active in the certification of all Corps discharge permit applications.

Connecticut

There are state laws regulating both inland wetlands and coastal wetlands in Connecticut. Section 404 has jurisdiction over some areas that the state also regulates, and applications must be independently made to both the Corps of Engineers and the Connecticut Department of Environmental Protection. If a municipality has satisfied the requirements of the law, it may regulate its own wetlands based on State Statute. In those cases, the applicant must apply through that municipality rather than the State Department of Environmental Protection.

Delaware

Delaware has a state permit program regulating fill activities and participates in the certification of Corps Section 404 permit applications. The state law is very similar to the Federal law, and the newly adopted Wetlands Regulations forbid the placement of any nonbiodegradable material onto areas classified as wetlands by the Department of Natural Resources and Environmental Control. There are about ten applications per month for projects in subaqueous lands and wetlands.

Florida

Florida is very active in the regulation of all filling activities. The state is in the process of developing a joint permit application with the Corps in which one discharge permit application will be filed by an applicant, and the state and the Corps will issue a joint public notice. The burden is generally on the applicant to provide for any sampling as well as reasonable assurance of no water quality degradation. The state conducts a biological survey of the area before a permit is issued and it is their goal to conduct a post-construction environmental inspection but personnel are limited. There are agreements between the State Department of Environmental Regulations and approved local programs for conduction of field surveys and processing of applications (except for final approval) on behalf of the state agency for small, non-controversial projects. Comments on fill applications are received from various state agencies and interested organizations depending on the nature of the project. Requests for filling biologically valuable areas including wetlands are carefully reviewed, and filling in these areas is discouraged. The state may put conditions on the permit to safeguard water quality. This may include stabilization of the fill by revegetation or by riprapping; also, the state may request water-quality modeling.

Georgia

A state permit is required in coastal marshlands but there is no state law directly regulating fill activities in Georgia. The state certifies discharge permit applications under Section 401 of P.L. 92-500 and reviews all public notices.

Hawaii

Hawaii reviews and certifies all Corps discharge permit applications but does not have a state permitting program.

Idaho

Idaho has a Stream Channels Alteration Act and a Lake Protection Act in which filling activity is regulated and a permit is required. These permits are circulated for review among other state agencies. Processing normally takes from 30 to 60 days, with other state agencies being allowed 20 days to comment on proposals. For certain types of projects minimum standards have been adopted and review only takes about 10 days. Corps discharge permit applications are also reviewed and commented on by the state. The Idaho Department of Health and Welfare must certify that proposals for Corps permits will meet state water-quality standards in order for such proposals to be approved.

Illinois

The Illinois Environmental Protection Agency individually reviews Corps permit applications and takes an appropriate certifying action of grant, deny, or conditional waiver as deemed necessary to ensure that the state water-quality regulations are not violated. Duplicate copies of the application are sent to the Department of Transportation in the Division of Water Resources for comment. This Department has the responsibility to carry out the state program. Permits are presently issued only for those filling projects which serve to straighten the shoreline of a particular stream. There is also a new floodplain regulation program in Illinois which provides for broader jurisdiction over filling activities, but which has been implemented to date in only a few basins in the Chicago area.

Indiana

The Indiana Flood Control Act of 1945 as amended by Public Law 122, Acts of 1973, is used to regulate filling activities. This state regulation is very similar to Corps permit regulations. Corps permits are also certified by the state to make sure no water-quality standards are violated. No general permits have as yet been issued with the Corps.

Iowa

Both the Iowa Natural Resources Council (INRC) and the Iowa Conservation Commission (ICC) have rules and regulations and active programs for the issuance of permits. These agencies are also active in the review and certification of Corps applications for dredging and filling. The Department of Environmental Quality (DEQ) does review and certify, or waive certification, on each application for dredge or fill activity sent to it by the Corps and/or individual applicants. The applications are reviewed by the DEQ only to ensure that water-quality standards are not exceeded by the proposed activity. This includes evaluation of suspended solids and turbidity relative to the designated beneficial use and standards for the specific stream in question. The ICC exercises jurisdiction over the bed and banks of all meandering streams in Iowa, including the Mississippi and Missouri Rivers among others. Regulations of the ICC require a permit for any type of work done on or over these stream beds. If a project involves floodway or floodplain construction, approval from the INRC may be required.

Kansas

Kansas has an active permit program comparable to the Federal permit regulations, but applications for state permits are processed separately from applications under the Federal program.

Kentucky

There is good cooperation with the Corps of Engineers and the state issues a letter of certification on all Corps public notices. General permits have been issued for such activities as boat ramp and private dock construction. The state requires a permit only if the project obstructs navigation or flow.

Louisiana

Corps discharge permit applications are reviewed and certified in Louisiana, but there is insufficient staff to conduct adequate field investigation of each permit. Currently, the state is working on a general permit for highway projects and it issues a letter of no objection for such projects as bulkheads and bridges. There is no specific state permit program regulating fill projects.

Maine

Maine works closely with the Corps, especially with dredging activities, and there is no activity with wetlands at this time. There are no general permits or joint public notices. These are being attempted but there are legislative problems. One problem is that there is a different amount of time required for review of these application procedures. Maine does have a wetlands law which is similar to Federal regulations. A state permit is required before a Corps discharge permit application is certified, with the state permit including a water-quality certification.

Maryland

Maryland is very involved with Section 404 permit certifications and does restrict filling activities within the state. There is a tidal wetlands law (1970) in which most of the activity is centered. The state has set up a joint public hearings procedure for large projects with the Corps. Comments from interested agencies are received but there is much duplication of effort. Environmental evaluation of projects is restricted by the size of the staff. A hydrologic review is often conducted by staff engineers and biologists working in the wetlands section. Already published studies are frequently used to assess the biology of the proposed site and, if needed, the applicant may be required to conduct an environmental study.

Massachusetts

The state permit program is similar to the Corps program under Section 404. The state is also active in certification of Corps discharge permit applications.

Michigan

The Great Lakes Submerged Lands Act (1955) and the Inland Lakes and Streams Act of 1972 are used to regulate dredge and fill activity in Michigan. There were about 3,500 applications submitted under these acts in 1976. The regulations are similar to Corps regulations, with the same general information required. Review is the same for the state and Federal permit applications except they are sent to different agencies for review. There is duplication of effort in the states' review and certification of their own permit applications as well as those of the Corps.

Minnesota

A state permit is generally required before a Federal discharge permit application is filed. There are no major problems with review or evaluation but the state has been swamped with minor projects. For these they generally send a letter of no objection along with a few guidelines. Dredging activities predominate among the project types, and close attention is given to hydraulic dredging. After the state permitting procedure is completed the Corps discharge permit application is easily evaluated.

Mississippi

Mississippi does not have a state permit program but is active in the certification of Corps discharge permit applications to ensure the activity will not degrade water-quality standards. The only problems are from staff limitations. General permits are prepared for projects such as piers, boat shelters, boat ramps, and riprapping. Other state agencies are used for review of pertinent discharge permit applications.

Missouri

Water-quality certification is made by Missouri on all Corps discharge permit applications. The process takes about 3 to 4 weeks. General permits are being developed. There is no state regulation of fill activities, and before the Federal program there was no regulation at all.

Montana

Montana law allows temporary violations of water-quality standards due to short-term construction, provided provisional authorization has been given. Before this authorization is given, the Water Quality Bureau checks with the Fish and Game Department, Soil and Water Conservation Districts, or other designated agencies to see if the applicant has approval under the Natural Streambed and Land Preservation Act of 1975. This approval is for private party projects. If the project is being proposed by a government agency the approval must be obtained from the Fish and Game Department under the Stream Preservation Act of 1963. In the certification process for Corps discharge permit applications a joint public notice is issued.

Nebraska

Nebraska is not directly involved with Corps discharge permit applications for the regulation of fill material. There is maintenance dredging on the Missouri River but these activities have needed permits since 1899. Other than this there is no state-administered permit program regulating fill projects.

Nevada

There is no state law pertaining to the regulation of fill projects, and the state is not involved with any Corps discharge permit applications. Fill discharge permits are taken care of by the Corps.

New Hampshire

The state wetlands act (since 1970) is considered to be more comprehensive and restrictive than the Federal regulations; therefore, New Hampshire relies on its own program and is not very active with the Federal permitting procedure. From 1,500 to 2,000 projects per year are reviewed by a 15-man board that meets weekly. About half of the applications need some field investigation, but in the rest of the cases the board is familiar with the area. It takes about 3 weeks for review of a permit application and no fee is charged. All projects regardless of size must make an application. The Corps processes their application only after state approval. The board reviews any project applications received by the Corps but only comments on them and is not involved with certification.

New Jersey

New Jersey does not have any state-wide permit regulations for dredging or filling activities, but they are involved with certification of Corps discharge permit applications. About three applications per month are reviewed and comments from other state agencies are obtained. Filling activities in coastal wetlands are carefully regulated by the state.

New Mexico

There are parts of five Corps Districts within the boundaries of New Mexico. Only one, the Albuquerque District, had by February 1977 issued permits which were reviewed by the state and certified as meeting water-quality standards. There is no state permit program to regulate dredge and fill activities.

New York

There is an active permitting program in New York, which is very similar to the Federal regulations. An environmental analysis is requested from the applicant prior to issuing a public notice. State certification of Section 404 discharge permit applications is also made. There is good cooperation with the six Corps Districts in the state. About 2,200 applications per year are received and a general permit has been issued for certain New York Department of Transportation projects.

North Carolina

State law in North Carolina regulates fill projects only in coastal wetlands and estuarine waters. Review and certification of Corps discharge permit applications is made.

North Dakota

There is not much activity with fill projects in North Dakota. There is no state law regulating the discharge of fill material but the Department of Health does certify Section 404 permit applications for the Corps. It is possible that under certain circumstances state water pollution control laws could conceivably regulate filling activities.

Ohio

There is no state law regulating fill activities except those pertaining to landfills. Ohio is not involved with Corps discharge permit applications.

Oklahoma

The Oklahoma Water Resources Board reviews and issues a water-quality clearance to all projects, small or large, which may have adverse effects on the quality of navigable waters in Oklahoma. These permits are issued for dredged or fill material in the navigable waters in accordance with Section 404 of P.L. 92-500. The Board reviews plans and specifications for various types of activities before a clearance is granted. A partial list of these activities includes bridge construction, pipeline construction, dredging and filling, bank stabilization, boat docks and ramps, and constructions of intake and outfall structures. At any time when a project is determined to have an adverse effect on the environment within the stream, the water-quality clearance can be revoked and actions taken to ensure that the water quality of the stream is not degraded.

Oregon

The Removal/Fill Law is very restrictive and regulates all fill activity exceeding 50 cubic yards in natural waterways. Oregon is also involved with certification of Section 404 discharge permit applications; however, this involves some duplication of effort with the state program.

Pennsylvania

Pennsylvania has a very active permit program regulating the discharge of dredge or fill material. The state is also involved with certification of Corps discharge permit applications.

Rhode Island

Regulation of dredge and fill activities is accomplished by the Division of Planning and Development in the Department of Natural Resources (fresh water wetlands) and by the Coastal Resources Management Council (marine areas). The program in Rhode Island is generally more restrictive than the Corps program, but the state is also active in certification of Federal discharge permit applications. General permits are currently being developed for minor (small) projects.

South Carolina

South Carolina has many agencies which comment and participate in the Corps program. The state must certify Section 404 permits and other Section

10 permits that require water quality certification. Without this certification, the permit cannot be issued. The South Carolina Department of Health and Environmental Control (DHEC) issues this certification. This certification is in accordance with Section 401 of PL 92-500 and state water-quality standards. The State participates with the Corps in a joint public notice and after the comment period, if the project is environmentally sound, certification is made by the State to the applicant with a copy to the Corps. South Carolina also has a general permit. South Carolina claims ownership of all lands below the average mean high water mark, thus necessitating a permit for all work below this mark. South Carolina's permit is issued by the Budget and Control Board. The State has created a Water Resources Commission which handles the permit. This Commission gathers all comments from the state agencies and from these comments recommends either denial or approval of the permit to the Budget and Control Board. Before the Water Resources Commission can recommend approval of the permit, all objections from the various state agencies must be withdrawn. Field inspections are made of sites by each agency as they deem necessary. General permits have been issued for docks, piers, and small bulkheads on large lakes. General permits also have been prepared for small bulkheads and navigation yards along the coast.

South Dakota

South Dakota reviews and submits verbal recommendations on all Corps discharge permit applications,but does not certify them. There is also no state law regulating dredge or fill activities.

Tennessee

There are four Corps Districts within Tennessee, and the state is active in the certification of Corps discharge permit applications. Some general permits are currently being developed. There is no direct state permit program, although the Water Quality Control Act applies to certain projects such as hydraulic fills.

Texas

There is no state law regulating dredge and fill projects, but Texas is involved with certification of Corps discharge permit applications, particularly along the coast. Some general permits have been issued, and cooperation between the various Districts and the state is good.

Utah

Very little activity has occurred in Utah with dredge or fill projects. There is no state law regulating this, and although they have not waived their right of certification, there has been no opportunity to use that right.

Vermont

Adequate legislation currently exists to regulate the discharge of dredge and fill materials in the waters of Vermont. Therefore, the Corps Section 404 permit program is essentially a duplication of effort. Vermont is working cooperatively with the Corps in the establishment of general permits to assist the public in expediting minor projects. Additional state legislation concerning activities in wetlands is appropriate and is currently being prepared.

Virginia

The Commonwealth of Virginia is very involved with the Section 404 permit program. The Virginia Institute of Marine Science investigates all applications for works in tidal waters, including adjacent wetlands. The resulting interdisciplinary analysis is distributed to local, state, and Federal agencies for review. There is considerable concern with the current definition of wetlands as contained in Section 404 regulations, and in the difference in elevations at which the state and Federal regulations apply. The Virginia Marine Resources Commission is also involved with the regulation of dredge and fill activities. Virginia also certifies Corps discharge permit applications, and the state has been getting involved with general permits primarily for small projects such as private pier contruction.

Washington

There is an active involvement by Washington with certification of Corps discharge permit applications. The state also has regulations and a permitting procedure which covers much the same activities as the Sec. 404 regulations.

West Virginia

West Virginia is involved with the certification of discharge permit applications from the Corps, but does not have a state permit program of its own.

Wisconsin

Dredge and fill projects are regulated by state law in Wisconsin. There are six regional offices which do a field check including some chemical water-quality measurements. Certification of Federal permits is also undertaken. At the present time the state application forms are being changed to conform more closely with the Corps forms, and other duplications of effort are being reduced through better cooperation. General permits have been issued for shoreline protection of Lake Michigan, shoreline protection and the construction of docks and bulkheads on Rock River, and certain transportation projects.

Wyoming

Wyoming has recently instituted a program for certification of dredge and fill activities under Section 404. A standardized application form is provided by the Department of Environmental Quality. The applicant must explain the rationale for the proposed time schedule, and present methodologies to be used to ensure there is no violation of state water-quality standards. Revegetation activities must be described.

Table C-4. Information required on permit applications for the regulation of fill material by selected states

INFORMATION REQUIRED[1]	Connecticut[2]	Delaware[3]	Florida[4]	Idaho[5]	Illinois[6]	Indiana[7]	Maine[8]	Maryland	Michigan[9]	Minnesota[10]	Montana[11]	New Hampshire[12]	New York[13]	North Carolina[14]	Oregon[15]	Rhode Island[16]	Vermont[17]	Virginia[18]	Wyoming[19]	States Requiring (%)
1. Owner or applicant and address	D	I	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	100
2. Worker (Contractor) and address			D		I				I		D	D	D		D	D	D		D	53
3. Location of project (general)	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	100
4. Type of project	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	I	D	100
5. Purpose or reason for project	D	D	I	D	D		D	D	D	D	I	D	D	D	D	D	D	D	I	95
6. Name of nearby water body affected	D	I	D	D	D	D	I	I	D	D	D	D	D	D	D	D	D	D	D	100
7. Salt or freshwater project	I	I	I									D	D			D			I	37
8. Start and Completion dates (length of project)	D	I	I	D						D	D	D	D	D	D	D	D	D	D	74
9. List of all abuting land owners	D	I	D		D		D		D			D		D		D	D	D		58
10. Description of construction planned	D	D	D	D	D	D	D	D	I	D	D	D	D	D	D	D	D	D	D	100
a. Type of material	D	I	I	D	I	D	I	I	D	D	D	D	D	D	D	I	D	D	I	100
b. Quantity of material dredged	D	D	D		I	I	I	I	D	D	D	D	D	D	D	I	D	D	I	95
c. Quantity of fill material	D	D	D		I	I	I	I	D	D	D	D	D	D	D	I	D	D	I	95
d. Final disposition of dredge material	D	D	I	I	I	I	I	I	I	D	D	D	E	D	D	I	D	D	I	95
e. Method of Operation	I	I	D	D	I	I	I	I	I	D	D		E	D	D	I	D	D	I	89
f. Distance flow of water to be rerouted	I	I	I	D				I			I	D	E			D			I	47
g. Structures planned on fill	D	D	I	D	I	I	I	I	I	I	I		E	D	I	I	I	D	I	89
h. Equipment to be used	I	I	D	D		I	D	I		D	D		E	D	I		I	D	I	74
11. Diagramatic Map	D	D	D	D		D	D	D	D	D	D	D	D		D	D	D	D	D	89
12. Survey Sheets	D		D												D					16
13. Detailed Plan	D	D	D	D	D	D	D		D	D	D	D	D	D	D	D		D	D	89
14. Length of work section	D	I	D	D	I	I	D	I	D	I	I		D	D	D	I	D		I	89
15. Location on stream	D	D	D	D	I	D	I	I	I	I	I	I	D	I	D	I	D		D	95
16. Use of state owned land	I	D	D		I		I	I	I				D	I	I					53
17. Name and address of local newspaper													D					D		11
18. Gradient of channel altered	I	I	D	D		D		I	D		D				I					47
19. Erosion control precautions	I		D	I	I		I	I		D	D		E	D	D	D		D	I	68
20. List of downstream water users					I		D										I			16
21. Municipal Services need			I					I		D				D		D				26
22. Alternatives considered	I	I	I						D	I	D		E							32
23. Marsh vegetation in area	I	I	D						I	I										26
24. Environmental Effects Anticipated	D	I	I	I	I		I		D	D	I		E	I	D			D	I	68
25. Maintenance and monitoring plan		I	I						D	D			E	I	I					32
26. Turbidity control	I		D	D	I		I	I		D	D	D		I	I	D	D	D	D	79
27. Pollution control	I		D	D	D		I	I		D	D			I	I			D	D	63
28. Activities planned to reduce detrimental effects	I	I	D	D	D		D	I		D	D		E	D	D	D		D	I	74
29. Chemical Tests	D		D					I		D			E					D	D	32
30. Field investigation (site description)	I	I	D	D				I				D	D		D	D		I		53
31. Environmental impact statement prepared										D			I							11
32. Estimated cost of project			I							I			E			D	D	D		26
33. Soil tests	D		I					I		D			E	I						26
34. Any present litigation against property			I		D				D											16
35. Certification or notarization	D		D	D	D	D	D	D		D		D	D					D	D	63
36. Application fee		D	D												D		D			21
37. Public hearing	D	D	D									D	D		I	D	D	I		47
38. Public notice		D	D				D				D		D		I	D		D		42
39. Present flow characteristics of water course	D		D					I							D	D			I	32
40. Mean high and mean low water lines on map	D	I	D	D	D	D	D	I	D					D	D	D				63
41. List existing permits	D	I	I				D							D		D				32
42. Cross sections	D		D	D	D			I		D	D				D	D	D	I	I	63
43. Dike design	D	I	D	D	I		I	I			D				I	D	I	D	I	68
44. Radiation analysis	D		I					I		I									D	26
45. Finfish and/or shellfish bed survey	D	I	I					I					D							26
46. Longshore drift directions	D		I																	11
47. Current velocities	D		I																	11
48. 100-year flood line	D																			5
49. Army Corps of Engineers permit	D		I			D		D	D				D							32
50. Evidence of local approval of project			D		D		D		D			D	I				D			37
51. Direction of flow of current			I	D				D	D						D	D			I	37
Questions per State (%)	80	61	93	49	51	34	53	61	49	58	51	39	44	49	63	59	46	53	56	----

Table C-4. (Concluded)

FOOTNOTES

[1] D - Directly asked
I - Indirectly asked
Blank - Information not requested
E - Covered by EIS, if required (New York only)

[2] Connecticut - Fifteen copies are required. Applicant may be required to submit an evaluation of the extent of plant species commonly associated with water courses, and an analysis of the probable effect of the proposed activity on the plant and animal ecosystem. Physical and chemical analyses are required for dredge and fill projects with a vegetation and animal survey sometimes required.

[3] Delaware - A minimum application fee of $50.00 per project. Other fees are required for some types of projects including costs of public hearings. There shall be no filling or dredging, other than maintenance dredging, in shellfish areas.

[4] Florida - Sixteen copies of the application must be submitted. Also, an aerial photograph is required. There is a $200.00 application fee ($150.00 for biological survey and water quality assessment and $50.00 for application processing). Wetlands or submerged lands are defined on the basis of a species list of dominant wetlands vegetation. This list is in the process of being updated. After initial review of the application, additional specific information may be required from the applicant depending on the nature of the proposed project.

[5] Idaho - Two copies of detailed plans and specifications are required. An aerial photograph is suggested.

[6] Illinois - The state retains for the use and benefit of the public all rights to any accretions which may accrue to the land as a result of the project.

[7] Indiana - One copy of the application and of the set of plans is required. Construction on the project must begin within three years of the date of application approval.

[8] Maine - The regulations apply only to coastal waters (salt water). Two types of permits are required: a Wetlands Alteration Permit and Water Quality Certification.

[9] Michigan - There is a $25.00 application fee. For any blueprints or drawings larger than 8½" x 11", five copies are required.

[10] Minnesota - Laboratory analyses on sediments shall include at least total volatile solids, oil and grease, chemical oxygen demand, total Kjeldahl nitrogen, lead, mercury, and zinc. Analysis for other pollutants may be requested for specific cases.

[11] Montana - A photograph is suggested as being useful.

[12] New Hampshire - Three copies of the notice shall be filed with the local town clerk. Public hearings are held on major proposals (about 75 yearly) and turbidity control requirements are issued on each permit by the Water Supply and Pollution Control Commission.

[13] New York - Three copies are needed of the application and drawings. A list of all abuting land owners is required for wetlands permits only. Field surveys are made by the Department of Environmental Conservation.

[14] North Carolina - Two copies of the application and work plan must be submitted to the state, and one copy of each must be presented to each adjacent land owner. An on-site investigation by the state is made for each application.

[15] Oregon - The application fee varies according to the site and type of project.

[16] Rhode Island - Two copies of the application along with a fee of $25.00 is required for the Department of Natural Resources. A fee of $35.00 is required by the Coastal Resources Management Council for projects within its jurisdiction.

[17] Vermont - A fee of $50.00, or $1.00 for each $1,000.00 estimated construction cost, whichever is greater, is required.

[18] Virginia - Bottom samples must be taken and analyzed for heavy metal content if deemed necessary.

[19] Wyoming - Two copies of an application are required, one to the Department of Environmental Quality and one to the Wyoming Game and Fish Department. After review by both departments, the Department of Environmental Quality makes the final decision on certification.

APPENDIX D: METHODOLOGIES FOR ENVIRONMENTAL IMPACT ASSESSMENT

Since the passage of the National Environmental Policy Act (PL 91-190), over 50 environmental impact assessment methodologies have been developed. This appendix focuses on a literature review of environmental assessment methodologies and has a comparative analysis of 42 environmental impact statements and 11 permits/Statements of Findings prepared since Sec. 404 requirements were initiated in 1972. The basic objectives of these activities were to determine if existing environmental impact assessment methodologies could be used in projects involving the discharge of fill material and, secondly, to utilize a selected methodology as a baseline for comparison of the extent to which various environmental impacts of fill material discharge are addressed in environmental impact statements, permits, and Statements of Findings.

Purposes of Environmental Assessment Methods

Consider all environmental factors

There are several purposes served by impact analysis methods (Canter, 1977). One purpose is to ensure that all environmental factors which need to be considered are included in the analysis. This is necessary because the environment is a complex system of physical-chemical, biological, cultural, and socio-economic resources with which various actions can have complex impacts and interactions. Methods which provide the analyst with approaches for systematically considering environmental factors are desirable.

Evaluate alternatives

Another purpose of impact analysis methods is to provide for evaluation of alternatives on a common basis. Impact statements should describe the environmental impacts of all alternatives and not just summarize the relative economic evaluation of alternatives to the proposed action. Methods for impact analysis should provide a means for evaluating the absolute, or at least the relative, impact of alternatives. In conjunction with impact evaluation, it may be determined that there are data deficiencies for description of the environmental setting, for impacts associated with the proposed action, or for use of technology for impact prediction and assessment. Methods for impact analysis can aid in identifying data needs, and this information can be utilized as a basis for special studies or field studies.

Evaluate mitigation measures

Another important purpose of methods of impact analysis is associated with evaluation of mitigation measures. Direction of attention to measures which will minimize the environmental impact of alternatives and the proposed action should be accomplished. Methods for impact analysis can aid in evaluation of the effectiveness of potential mitigation measures.

Inform the public

Another purpose for an assessment methodology is to enable the development of information in summary form which can be used in a public participation program. The utilization of a systematic (all-inclusive), interdisciplinary, and organized approach gives credence to the validity of the impact analysis. Care must be exercised so that public distribution of information does not appear to represent an attempt on the part of the preparers to mislead, misrepresent, or confuse the results. Information from impact methodologies which is presented to the public should be in summary form only, with appendices or attachments as necessary.

Comply with NEPA

Finally, a key purpose of methods for impact analysis is to ensure compliance with the spirit and intent of NEPA. This is particularly relevant since Part B of Sec. 102 of NEPA called for agencies to develop methods and procedures to ensure that environmental amenities were included in decision making.

Categories of Environmental Impact Methodologies

As methods for impact analysis have developed, there have been periodic comparisons of methodologies in accordance with predetermined evaluation criteria (Dickert, 1974; Warner and Preston, 1973; Warner and Bromley, 1974; Smith, 1974; Jain and Urban, 1975; and Canter, 1977). In each of these analyses, delineation of selected evaluation criteria for methodology comparison and grouping was accomplished, and then selected methodologies were compared based on their degree of compliance with the evaluation criteria. Warner and Bromley (1974) divided impact methodologies into five main classes: ad hoc procedures, overlay techniques, checklists, matrices, and networks. Jain and Urban (1975) added a sixth class -- combination-computer aided.

Ad hoc procedures

Ad hoc procedures involve little more than assembling a team of specialists to identify impacts in their areas of expertise with minimal guidance beyond the points of the requirements of NEPA. This methodology was utilized by all Federal agencies in the period immediately following the enactment of NEPA.

Overlay techniques

Overlay techniques are well-developed approaches utilized in the fields of land-use planning and landscape architecture. The basic approach is to use a series of overlaid maps of environmental factors or land features to discern between design alternatives. The overlay approach is generally effective in selecting alternatives and identifying certain types of impacts, but it does not quantify impacts or identify interactive components. Overlay techniques can be computerized for more effective data analyses.

Checklists

Checklist approaches list the impacts which are typically associated with particular categories of projects. From a master list of environmental factors and/or environmental impacts, impact statement preparers select and evaluate those impacts anticipated for the particular project situation. There are four broad categories of checklists which can be defined (Canter, 1977). Simple checklists include a list of parameters; however, no guidelines are provided on how environmental parameter data are to be measured and interpreted. Descriptive checklists include an identification of environmental parameters, and guidelines are provided on how parameter data are to be measured. Scaling checklists are similar to descriptive checklists with the addition of information basic to objective scaling of parameter values. Scaling-weighting checklists represent scaling checklists with information provided as to subjective weighting of each parameter with respect to every other parameter.

Matrices

Matrix approaches are expanded checklist methods in which a list of possible project activities is established along one matrix axis, with a list of potentially impacted environmental characteristics or conditions along another matrix axis. The approach differs from a checklist in that an attempt is made to identify the various causal factors (project actions) producing each impact. Stepped matrices represent a second-generation matrix approach which involves the identification of secondary interactions resulting from primary changes delineated in an initial matrix. Tertiary interactions can be shown through the use of additional matrices.

Networks

Network approaches expand upon the idea of a matrix by introducing a cause-condition-effect network which allows identification of cumulative or indirect effects not adequately explained through simple cause-effect sequences such as represented by matrices.

Combination-computer aided

These methodologies use a combination of matrices, networks, and analytical models in a computer-aided systematic approach to (1) identify activities associated with implementing major Federal programs, (2) identify potential environmental impacts at different user levels, (3) provide guidance for abatement and mitigation techniques, and (4) provide analytical models to establish cause-effect relationships to quantitatively determine potential environmental impacts (Jain and Urban, 1975).

Summary

Based on the comparative studies of environmental impact assessment methodologies, the general conclusion is that no single methodology has been developed which would be consistent as an optimum approach for identifying, quantifying, and assessing the potential impacts associated with project development. Features of certain of the methodologies can be utilized in the development of ad hoc procedures which can be utilized for meeting the environmental impact assessment needs for individual projects. In terms of the six categories of methodologies delineated above, the checklist approach is the dominant type followed by the application of matrices. Utilization of networks, overlay techniques, and combination-computer aided methods have been minimal. Ad hoc procedures still represent viable approaches since they can be developed based on portions of other methodologies, and they can be used on a more scientific basis than the ad hoc procedures of the early 1970's.

A Methodology Pertinent to Section 404 Permits

Based on the review of over 50 environmental impact assessment methodologies, only one methodology (Carstea et al., 1975) was identified that has been specifically developed for the purpose of providing instructions on how to conduct an impact assessment for certain projects requiring Sec. 404 permits. The objective of the methodology, developed by Mitre Corporation, was to describe the probable environmental impacts (physical, biological, and socio-economic) of representative structures and common activities performed in coastal waters of the northeastern United States. The second purpose was to prepare procedural and technical guidelines for an effective and rapid environmental assessment review of specific permit applications. The following actions/projects were addressed: riprap placement; bulkheads; groins and jetties; piers, dolphins, mooring piles, and ramp construction;

dredging (new and maintenance); outfalls, submerged lines, and pipes; and aerial crossings. For each of the actions/projects considered, the following areas of environmental impact were summarized: erosion, sedimentation, and deposition; flood heights and drift; water quality; ecology; air quality; noise; safety/navigation; recreation; esthetics; and socio-economics.

The Mitre Corporation methodology (Carstea et al., 1975) can be defined as a checklist methodology. Use of the system involves identification of the type of structure or activity to be considered. Referral is then made to a discussion of the specific activities associated with the typical structure or activity under consideration. Information is compiled on the main activities associated with each typical structure of the project and the type and amount of equipment required for conducting these activities. Examples of these activities include transport of construction material, placement of riprap or landfill materials, and other items. A case study is presented for each structure/project to delineate the specific procedures to be utilized for impact quantification relative to water quality, erosion, sedimentation and deposition, flood heights and drift, ecology, and other items. Appropriate tables and graphs are provided to enable the computation of actual noise emissions, air pollutant emissions, sediment loads, water pollutant loads, and other impacts associated with various structures/activities in the coastal zone.

Due to the general useability of the Mitre Corporation methodology, this particular methodology should be made available to each Corps District Office in order to facilitate the environmental impact assessment process associated with Sec. 404 permit procedures.

Methodologies by Type of Project

As stated earlier, no methodologies have been developed that are applicable to all types and sizes of projects which may involve the discharge of fill material. This section will identify certain methodologies which have been developed for specific types of projects, with the underlying implication that if a project of a particular type is encountered, then it would be of value to be familiar with the methodology suggested herein in order to make a thorough environmental impact assessment. Table D-1 lists various project types which may involve the discharge of fill material and specifies pertinent categories of methodologies discussed herein which would be relevant for the listed project types.

Table D-1. Environmental impact assessment methodologies for project types

Structures and impoundments---placement of fill that is necessary to the construction of any structure; the building of any structure or impoundment requiring rock, sand, dirt or other pollutants for its construction.	Water Resources
Site development---site-development fills for recreational, industrial, commercial, residential, and other uses.	Coastal Development Housing Development Military Activities
Causeways/road fills---causeways or road fills.	Highways
Property protection---dams and dikes; artificial islands, property protection and/or reclamation devices such as riprap, groins, seawalls, breakwalls, and bulkheads and fills; beach nourishment; levees.	Water Resources
Pollution control and other---sanitary landfills; fill for structures such as sewage treatment facilities, intake and outfall pipes associated with power plants, and subaqueous utility lines; and artificial reefs.	Sanitary Landfills Pipelines Sewage Treatment Plants

Even though the emphasis to this point has been on methodologies per se, it should be noted that agencies have developed environmental impact statement/environmental impact assessment guidelines which may be extremely useful. Use of guidelines prepared by both Corps and non-Corps agencies may be of value for particular types of projects.

Water resources

Water resources projects include dams, dikes, levees, and causeways. Several environmental impact assessment methodologies have been developed for water resources projects. One methodology focuses on the various environmental impacts from dredging (Battelle Memorial Institute, 1974). A recent study by Solomon et al., (1977) has summarized the salient features of eight water resources impact methodologies. These methodologies were selected following an initial screening of over 50 methodologies, with the purpose of the screening being to identify those that had been developed that were pertinent to water resources. A summary of these features is shown in Table D-2.

Each of the methodologies identified in Table D-2 is classified according to whether it is a checklist or a matrix. There are three descriptive checklists, two scaling checklists, and three weighting-scaling checklists. Additional information is related to the variables considered, the approaches utilized for weighting and scaling, and the methods for impact summarization and presentation. The Battelle dredging assessment methodology (Battelle Memorial Institute, 1974) is pertinent for the discharge of fill material.

The Battelle dredging assessment methodology was developed to predict the direct and indirect changes which occur to an area's physical, biological, aesthetic, economic, and social environment. Once the immediate and surrounding regions have been defined, two interaction matrices (primary and secondary) are used to develop a checklist. Primary interactions are grouped according to the following project activities: planning and preconstruction, construction, dredging, disposal (open water, marsh, and upland), site disposition, and project use. To determine direct impacts, pertinent activities are selected (rows) and impacts tabulated (columns). Many direct impacts also contribute to indirect impacts; the direct environmental, economic, and social impacts from the primary matrix constitute rows of the secondary matrix. It is compared against the indirect impacts listed in columns. By reading across the rows the user identifies potential indirect impacts produced. Reading down the columns a user gains an appreciation of the multiple ways in which indirect environmental, economic, and social impacts occur. One of the most useful features of the

Table D-2. Summary of salient features of eight water resources impact methodologies

Methodology	Type of Methodology	Variables Considered	Weighting Approach	Scaling Approach	Impact Summarization
Battelle Environmental Evaluation System (1972)	Weighting-scaling checklist	Good listing of biological physical-chemical, aesthetic and cultural variables. Less emphasis on many factors associated with SWB* and RD* accounts. The variables listed are well described in terms of measurement units and evaluation. No information is provided on technical aspects of impact prediction.	Use of ranked pair wise comparison technique for allocation of importance weights to system variables.	Use of function graphs with scale of 0 (bad) to 1 (good).	Products of importance weights times scale values are tabulated and presented by major environmental categories as well as the totals for all categories.
Tulsa District (1972)	Weighting-scaling checklist; also called matrix by preparers	Has good list of variables for EQ* SWB, and RD accounts. Minimal information is provided on definitions, measurement, and evaluation of variable. No information is provided on technical aspects of impact prediction.	Assignment of importance weights to variables by collective professional judgement of interdisciplinary team.	Use of relative scale of +5 (most) beneficial plan) to 0 (no action alternative) to -5 (most detrimental plan).	Products of importance weights times relative impact values are presented by major environmental categories as well as the totals for all categories.
Multi-agency Task Force (1972)	Scaling checklist	Good listing of variables for biological, physical-chemical, aesthetic and cultural environments. Minimal emphasis to a number factor in current SWB and RD accounts. The variables listed are well described in terms of measurement units and human influence considerations. No information is provided on technical aspects of impact prediction.	No numerical system used. Importance weighting based on collective professional judgment of interdisciplinary team.	Use of quantitative data plus quality scale of 10 (good) to 0 (bad), and human influence scale of 10 (good) to 0 (bad.	Quantitative data are presented for each variable along with quality scale values and human influence scale values.
Environmental Impact Center (1973)	Descriptive checklist	Has good list of variables for biological and physical-chemical environment. Emphasis is also given to many factors in the SWB and RD accounts, and their interrelationships with both the natural systems and the human system. For certain biological and physical-chemical variables, information is provided on impact prediction.	No numerical system used. Importance weighting based on collective professional judgment of interdisciplinary team.	Quantitative impact predictions are used. No special scaling system involved Collective professional judgment of interdisciplinary team is utilized.	Quantitative impact predictions are presented. No numerical weighting or scaling methods are utilized.

(Table D-2, continued)

(Table D-2, concluded)

Methodology	Type of Methodology	Variables Considered	Weighting Approach	Scaling Approach	Impact Summarization and Presentation
Battelle Water Resource Projects (1974)	Descriptive checklist	Primary orientation is to reservoir projects. Good listing of variables for EQ, SWB, and RD accounts. The variables listed are well described in terms of measurement units and evaluations. Information is provided on the technical aspects of impact prediction for water quality and ecological impacts.	No numerical system used. Importance weighting based on collective professional judgment of interdisciplinary team.	Quantitative impact predictions are used. No special scaling systems involved. Collective professional judgment of interdisciplinary team is utilized.	Quantitative impact predictions are presented. No numerical weighting or scaling methods are utilized.
Batelle Dredging Assessment (1974)	Descriptive checklist	Primary orientation is to dredging projects. Good listing of variables for EQ, SWB, and RD accounts. The variables are well described in terms of measurement units and evaluation. Information is provided on the technical aspects of impact prediction for many parameters.	No numerical system used. Importance weighting based on collective professional judgment of interdisciplinary team.	Quantitative impact predictions are used. No special scaling system involved. Collective professional judgment of interdisciplinary team is utilized.	Quantitative impact predictions are presented. No numerical weighting or scaling methods are utilized.
Lower Mississippi Valley Division (1976)	Weighting-scaling checklist	Good listing of natural environment variables for EQ account. No emphasis given to SWB and RD accounts. Information is provided on the measurement units and evaluation of variables. No information is provided on the technical aspects of impact prediction.	Assignment of importance weights to system variables by collective professional judgment of interdisciplinary team.	Use of quantitative data plus function graphs with scale 1 (good) to 0 (bad).	Product of acres of habitat types times scale values times important weights are presented by habitat type. Totals for all habitats in an area can be evaluated.
SCS Guide to Environmental Assessment (1976)	*Scaling checklist*	Good listing of variables for EQ account. Minimal emphasis on variables for SWB and RD accounts. The variables listed are well described in terms of measurement units. No information is provided on technical aspects of impact prediction.	No numerical system used. Importance weighting based on collective profesfional judgment of interdisciplinary team.	Use of quantitative data plus quality scale of 5 (excellent) to 1 (unsuited) for various resource uses.	Quantitative data are presented for each variable along with resource use scale values.

*SWB - social well-being
RD - regional development
EQ - environmental quality

After Solomon et al. (1977)

Battelle dredging assessment method is its inclusion of extensive information on the 84 environmental factors utilized, thus the method is termed a descriptive checklist.

The environmental impacts of water resources projects can also be assessed through the use of a series of review questions. These are questions which would be posed by a review agency such as the EPA. Guidelines for the preparation of environmental impact statements which are basically oriented to outlines/questions associated with various types of projects have been prepared by Region X of the EPA (Environmental Protection Agency, (1973). Questions/guidelines are presented for highway projects, dredging and dredged material disposal projects, land management, airports, and water resources development projects, among others. The EPA has also issued guidelines for review of environmental impact statements on projects involving impoundments (Curran Associates, 1976). This particular document was prepared in order to describe the anticipated environmental impacts resulting from impoundment projects and to serve as a document which can be used for the review of projects involving impoundments.

Coastal development

Twiss and Sorensen (1972) have delineated an environmental impact assessment methodology based on the network approach. The concept is that the actions of a project can reasonably be expected to produce changes in one or more environmental conditions, which in turn will generate subsequent environmental condition changes until some relatively terminal effect or impact is reached.

Groat and Brown (1972) presented the concept of an interaction matrix to identify potential environmental impacts associated with various activities in the coastal zone. This matrix approach identifies a potential impact associated with the given activity and then develops specific quantification of the anticipated impacts relative to the environmental setting.

Moore et al. (1973) developed an environmental impact matrix for describing the relationships between typical manufacturing activities and their potential ultimate impact on the three regions of the Delaware coastal zone. This stepped matrix measures potential for environmental damage and the general magnitude of potential degradation on a four-level scale. Familiarization with this methodology, even though it was not specifically developed for the discharge of fill material, would be quite useful for projects involving development in the coastal zone.

Odum (1972) proposed the use of energy diagrams for describing the impacts associated with various project types. Energy circuit diagrams may offer advantages for organizing information, for improving presentations, and, ultimately, for aiding understanding and prediction. The energy diagram, through the use of a set of symbols, shows the flows of all energies in the system, keeping track of the main components of the system such as the plants, animals, chemical processes, reservoirs of resource storage, flows of information, and outside actions that cause change. Energy diagrams have been utilized to predict the impacts of waste discharges on the Baltic Sea and for a marine meadows ecosystem located near Fort Myers, Florida. The steps in preparing an environmental impact statement using energy diagrams are summarized in Odum (1972).

Although the concepts embodied in the use of energy diagrams are scientifically valid, two primary difficulties are associated with the use of this impact assessment methodology

1. Many of the processes, and particularly the rates of change in the processes, are simply unknown.
2. The use of a system such as this requires a high degree of technical sophistication as well as backup resources such as computer facilities.

Housing development

The creation of fastlands for subsequent development for purposes of providing housing is one of the major types of projects requiring fill material discharge. An extensive scaling checklist approach, which also incorporates the concept of an interaction matrix to identify potential impacts, has been developed for the Department of Housing and Urban Development (HUD) (Voorhees and Associates, 1975). In this method, all projects associated with housing and urban development are subjected to an initial screening for the purpose of directing the evaluators to potential problem areas, highlighting the potential benefits, and, in general, organizing the total environmental assessment. Higher level tests would then be applied only in potential problem areas; in most cases, these tests will demand particular professional expertise until a final decision is made.

The methodology divides the environment into seven physical components and seven social components and utilizes a basic interaction matrix to delineate the potential impacts of various types of development projects on the 14 components. The methodology considers three categories of development in both metropolitan cities and satellite communities: fully developed (central areas), partially developed (suburban areas), and new areas (rural/fringe).

Following the identification of potential impacts, the HUD methodology provides additional information on how to address and scale particular identified impacts. The significance of a particular project (alternative) can be determined through an objective evaluation of project impacts in relation to their magnitude, exposure, timing, permanence, extent, relative importance, and interaction among other components.

Military activities

The discharge of fill materials has been utilized in meeting various construction and land creation needs at military installations. The Department of the Army has a methodology which is useful for conducting environmental assessments of military activities (U.S. Dept. of the Army, 1975). The methodology can be considered as a descriptive checklist or as a combination computer-aided methodology. The steps involved in use of the methodology are as follows:

Step 1. Identify the need for an EIA or an EIS;
Step 2. Establish details of the proposed action;
Step 3. Examine environmental attributes, impact analysis worksheets, and summary sheets;
Step 4. Evaluate impacts using attribute descriptor package;
Step 5. Summarize impacts on summary sheet;
Step 6. Examine alternatives;
Step 7. Address the eight points of CEQ Guidelines;
Step 8. Process final document.

Examples of representative Army actions that might have a significant environmental impact (Step 1) are given, and guidance is provided in the identification of Army activities (Steps 2 and 4) in nine functional areas as follows:

1. Construction;
2. Operation, Maintenance, and Repair;
3. Training;
4. Mission Change;
5. Real Estate;
6. Procurement;
7. Industrial Activities;
8. Research, Development, and Test and Evaluation;
9. Administration and Support.

The methodology further identifies and characterizes environmental attributes (Steps 3 and 4) in detail via "descriptor packages." The 46 attributes are classified into seven categories as follows:

1. Air,
2. Water,
3. Land,
4. Ecology,
5. Sound,
6. Human,
7. Economic.

For each of the attributes that are delineated, specific information is provided on the following:

1. Definition.
2. Army activities which effect the attribute,
3. Source of effects,
4. Variables to be measured,
5. How variables are measured,
6. Evaluation and interpretation of data,
7. Special conditions,
8. Geographic and temporal effects,
9. Mitigation of impact,
10. Other comments,
11. References or other information sources.

Specific lists of various types of actions are provided for each of the Army activities which have been classified into nine functional areas. Information is also included for the 46 environmental descriptors used in the impact assessment methodology. On the impact analysis worksheet, impacts are identified as to whether they are expected to be negative or beneficial. Summarization of the impacts involves the algebraic addition of all beneficial and detrimental changes.

The Department of the Air Force has also issued a Handbook for Environmental Impact Analysis (Jain et al., 1976). This handbook was developed for the various activities associated with Air Force operations. It is similar in concept to the Department of the Army methodology in that it draws heavily on the usage of an interaction matrix to identify potential impacts and provides extensive information on how to collect necessary information and evaluate potential impacts.

Highways

Several environmental impact assessment methodologies have been developed for highway projects, and since highway projects involving the use of fill represent a key type of project requiring Sec. 404 permits, familiarization with representative methodologies is valuable. One methodology, developed by Adkins and Burke (1974), is a checklist using a +5 to -5 rating system for evaluating impacts, but no specific guidelines are provided for measuring impacts. The approach was developed to deal specifically with evaluation of highway route alternatives. Parameters utilized in this methodology are categorized into transportation, environmental, sociological, and economic groups. Route alternatives are scored +5 to -5 in comparison to the present state-of-the-project area, not the expected future state without the project. Since the approach uses subjective relative estimations of impacts, the data, man-power, and cost requirements are flexible. An interesting feature of the methodology is the method of summarizing the number as well as the magnitude of plus and minus ratings for each impact category. These summarizations are additive and thus implicitly weigh all impacts equally.

A six-volume Environmental Assessment Notebook Series issued by the Department of Transportation (1975) represents the most complete assessment methodology on transportation projects. It can best be categorized as a descriptive checklist approach. The Notebook Series seeks to better integrate the transportation planning and environmental impact assessment processes. Techniques for conducting social, economic, and physical impact analyses as means of facilitating and improving the quality of the environmental assessment process and organizing the findings in a readily usable form are presented.

Notebook I discusses the principles of transportation planning and considerations which should be incorporated in all phases of the highway planning process (Department of Transportation, 1975). Notebooks II through IV provide a comprehensive list of potential social, economic, and physical impacts on highway projects, together with workable state-of-the-art methods and techniques for impact identification, data collection, and analysis and evaluation. Notebook V describes techniques for recording, organizing, and communicating pertinent findings of the transportation planning and impact assessment process. Notebook VI expands the bibliographic references contained in the other notebooks and lists other data and information which may be helpful to professionals responsible for environmental impact assessment.

An environmental impact assessment methodology involving a weighting-scaling checklist was utilized for the metropolitan Atlanta rapid-transit system (Smith, 1974). The methodology was applied to one rail line of the rapid-transit system and consisted of using a number of value functions for converting information on a wide variety of dissimilar environmental effects to commensurable quantitative units. This conversion permitted the aggregation and evaluation of the overall environmental impact of an alternative and of trade-offs among alternatives and individual effects. This particular methodology offers a very unique and innovative approach to assessing the environmental impacts of transportation facilities.

Sanitary landfills

Although no separate environmental impact assessment methodologies have been developed for sanitary landfills, several references identify the general considerations associated with preparing environmental impact statements for sanitary landfill projects. The approach by Stearns and Ross (1973) can be considered as a simple checklist. Five basic components were suggested for inclusion in an environmental impact statement:

1. Description of the proposed sanitary landfill and its locale;
2. Discussion of all foreseeable positive and negative impacts on the physical and social environments;
3. Discussion of measures planned to mitigate the adverse effects;
4. Coverage of alternatives to the proposed landfill site;
5. Conclusions - a subjective assessment of whether the potential good of the project will outweigh the potential harm to the environment.

The basic background and impetus for the project should be delineated in describing the proposed sanitary landfill and its locale. The beneficial as well as detrimental effects of the proposed landfill should be discussed. Positive effects are mainly related to public health concerns in that problems associated with rodents and flies will be minimized. Usage of the completed site for recreational purposes or some other function can also be a beneficial effect. Adverse effects can be classified into four major components, and some discussion should be provided on each of these effects. These major components include effects on the area's water and air quality and esthetic characteristics, effects on local and regional flora and fauna, effects on land and regional land use, and effects on social and economic characteristics. Many of the possible adverse effects can be mitigated if proper precautions are taken and correct sanitary landfill operating procedures are followed. A summary of some of the adverse impacts and counteractive measures which can be utilized is given in Stearns and Ross (1973).

The basic alternatives for a sanitary landfill project include no project at all, alternative locations for the sanitary landfill, and alternative means to dispose of solid wastes. The environmental impact statement should address the relative environmental impacts anticipated to occur from each of these alternatives. A recent study evaluated 69 landfill sites through the use of 20 evaluation factors and arrived at a site ranking which would allow the identification of those sites having the least environmental impact (Caffrey, 1975). The list of rating factors utilized in this study is suggestive of the types of factors which should be included in an environmental impact assessment to describe the relative environmental impacts of alternative sanitary landfill sites.

Pipelines

Construction of pipeline facilities in coastal areas and wetlands is of particular concern to the discharge of fill material because of associated backfilling around the pipeline and the preparation of a base material for pipeline construction. Guidelines for pipeline environmental impact statements issued by the Federal Power Commission contain simple checklists which can be utilized in environmental impact assessments (Federal Power Commission, 1973). One methodology has been specifically prepared to address the environmental aspects of gas pipeline operations in Louisiana coastal marshes (McGinnis et al., 1972).

Sewage treatment plants

In many instances fill material is required during the construction of sewage treatment plants. In the Federal government, the EPA is responsible for the preparation of environmental impact assessments/environmental impact statements for municipal sewage treatment plants. Extensive guidelines and reports are available on approaches for the preparation for environmental impact statements for sewage treatment plants.

A methodology has been developed for wastewater treatment plants by Dee et al. (1973). The methodology contains concepts of checklists, matrices, and networks. The basic approach consists of delineating 64 environmental parameters which are classified into four broad categories: ecology, physical-chemical, aesthetic, and social. Impact measurement involves the use of function graphs as well as an environmental assessment tree. The significance of impacts in each component is quantified by a set of assigned weights.

Methodologies for Socio-Economic Impacts

One of the major areas of deficiency in all environmental impact assessment methodologies is the lack of emphasis on potential impacts on the socio-economic environment. In the initial years (1970-73) of the preparation of environmental impact assessments/environmental impact statements, primary focus was given to the physical-chemical and biological environments. With increasing emphasis on secondary effects, and since many of these effects occur on the socio-economic characteristics of an area, increasing attention is being given to the socio-economic environment. Two methodologies addressing only socio-economic issues have been presented (Fitzsimmons et al., 1975; and Webster et al., 1976).

Fitzsimmons et al. (1975) presented a guide to the preparation of the social well-being account in conjunction with water resources projects. This methodology establishes the procedures for conducting research and analyzing data to forecast probable future impacts of implementing alternative water development plans (or no plans) and assessing their beneficial and adverse social effects upon people and their communities. The methodology is designed to meet the requirements of the Water Resources Council's "Principles and Standards for Planning Water and Related Resources," generally referred to as "Principles and Standards." The Principles and Standards mandate a four-account system to assess water development plans in terms of their social well-being (SWB), national economic development (NED), regional development (RD), and environmental quality (EQ) effects.

An economic impact forecast system (EIFS) has been developed by the Construction Engineering Research Laboratory of the U. S. Army (Webster et al., 1976). The EIFS uses information from the Department of Commerce (Bureau of Census and Bureau of Economic Analysis); Department of Defense; and Department of Health, Education, and Welfare to calculate, for Department of Defense projects or actions, the economic impacts caused by military activities. The EIFS estimates the impacts that expenditures of Federal dollars have on local businesses, households, and governments in the areas of employment, personal income, total business volume, housing revenues, housing and business interests, and government expenses. The system currently includes four operational functional areas: construction, operations and maintenance, mission change, and training. As development continues, the prediction equations will be refined and additional functional areas will be developed.

Comparative Review of Environmental Impact Statements, Permits, and Statements of Findings

In order to determine the thoroughness of the environmental impact assessment/environmental impact statement process used on projects involving the discharge of fill material, 42 environmental impact statements and 11 permits/Statements of Findings (four permits and seven Statements of Findings) were comparatively reviewed. The documents reviewed were selected based on the following procedures:

1. Examples of environmental impact statements/permits/Statements of Findings were requested from each of the 14 District/Division Offices visited in conjunction with this project.
2. The 102 Monitor, published monthly by the Council on Environmental Quality, was reviewed for potential environmental impact statements dealing with the discharge of fill material. The 102 Monitor was examined for the period 1971 through the fall of 1976; abstracts of environmental impact statements which seemed pertinent were identified; and the impact statements ordered/requested from the appropriate locations.

Environmental impact statements

A total of 101 environmental impact statements were selected for potential review. Out of this total, 48 environmental impact statements were not received or were received too late to be subjected to the review process (the cutoff date was January 10, 1977). For the 53 environmental impact statements that were received, the review procedure consisted of having each statement independently read by two individuals and then selected for additional review based on its relevancy to the discharge of fill material. Eleven environmental impact statements were eliminated in this screening process since they were not pertinent to the discharge of fill material. It is noted that the majority of the 42 environmental impact statements which were reviewed were prepared by the Corps of Engineers. The distribution of the 42 environmental impact statements (35 final and 7 draft) according to year of preparation, project type, and location is as follows:

Preparation	Number of EISs Reviewed
1971	2
1972	5
1973	4
1974	9
1975	13
1976	9

Type of Project	Number of EISs Reviewed
Structures and impoundments	3
Site development	5
Property protection	23
Pollution control and other	5
Dredging and filling	6

Location	Number of EISs Reviewed
Alabama	1
Arizona	1
California	7
Delaware	1
Florida	3
Georgia	2
Hawaii	4
Iowa	1
Louisiana	1
Maine	1
Massachusetts	1
Michigan	4
Nebraska	1
New Jersey	2
New York	2
Ohio	3
Oregon	2
Pennsylvania	1
Rhode Island	1
Texas	1
Washington	1

In order to provide consistency in the process of reviewing the 42 environmental impact statements, the 84 environmental items utilized in the Battelle dredging assessment methodology were used as the basis for identifying potential environmental impacts (Battelle Memorial Institute, 1974). This particular listing of items cannot completely describe all potential environmental impacts for all types of projects involving the discharge of fill material. Accordingly, the items that were used were intended only as a reference, and additional items could be included and/or deletions made as experience dictates. Usage of these 84 items was not intended to suggest that this particular listing of factors would represent an ideal impact assessment methodology.

It was the initial intention of the impact statement review to record when an impact statement indicated a potential impact on one of the 84 environmental items. In addition, each item addressed was to be further delineated in terms of the impact predictive method utilized as well as the method of impact significance evaluation. It was soon determined that very little information was available in the environmental impact statements on predictive methods and significance evaluation, so this portion of the review was deleted.

Table D-3 contains a summary of the impacts that were mentioned in the 42 environmental impact statements subjected to review. As can be seen, the most frequently mentioned impacts were as follows:

<u>Physical/Chemical</u>:	Turbidity (86%)*
	Erosion (52%)
<u>Ecological</u>:	Fish (83%)
	Benthos/epibenthos (67%)
<u>Aesthetic</u>:	Surface configuration (67%)
	Aquatic animals (57%)
<u>Economic</u>:	Sport fisheries (60%)
	Recreational navigation (51%)
<u>Social</u>:	Change in recreational assets (70%)
	Increased traffic (51%)

* Number in parentheses denotes % of the 42 reviewed EISs which addressed the stated impact.

A total of 35 of the 42 EIS's reviewed were prepared after the 1972 passage of the Sec. 404 requirements in PL 92-500. Accordingly, each of the 35 EIS's should contain some reference to Sec. 404; however, only 37% included such a reference. With regard to testing, only 18 of the 42 EIS's reviewed (43%) utilized some form of testing to predict or evaluate potential environmental impacts. The extent of testing ranged from simple fish trapping surveys to complete sediment and water analysis with elutriate testing and bioassay tests. The specific testing according to project type is identified in Table D-4. Testing was more frequently conducted for property protection projects, with sediment analysis being the most common type of testing procedure.

Table D-3: **Summary of review of selected environmental impacts**

Environmental Items	Description of Item	Times Addressed	Percent
Physical/Chemical			
Turbidity	Light reduction due to suspended materials	36	86
Erosion	Broad-scale environmental impacts on land	22	52
Dissolved O_2	Dissolved oxygen in water	21	49
Toxic Materials (water)	Heavy metals and synthetic organic materials	19	44
Nutrients	Phosphorus, nitrogen, and carbon	18	42
Suspended Solids	Sediment concentrations in a water course	16	37
Temperature	Temperature changes	16	37
Flow Patterns	Current patterns, flow velocity, discharge and water level.	14	33
Total Dissolved Solids	Aggregate content of dissolved carbonates, sulfates, etc.	13	30
pH	Intensity of acid or alkaline conditions	11	26
Flood Hazards	Hazards imposed or created by flood	10	23
Salinity	Dissolved minerals in water	9	21
Inflow (ground water)	Underground water change	9	21
Noise Intensity	Level of noise which is disturbing	9	21
Fecal Coliforms	Presence of fecal coliforms indicator	8	19
Duration of noise exposure	Duration of noise exceeding back-ground levels	8	19
Toxic materials (land)	Heavy metals and synthetic organic materials	7	16
Subsidence	Potential amount of settling	1	2

(Table D-3, Continued)

Table D-3 (Continued)

Environmental Items	Description of Item	Times Addressed	Percent
Ecological			
Fish	Migrant and resident fish	35	83
Benthos/ Epibenthos	Water body bottom-dwelling organisms	29	67
Terrestrial Communities	On soil in gaseous atmosphere	21	49
Rare and/or Endangered Species	State and Federal rare or endangered species	19	44
Terrestrial Vegetation	Autotrophic component of a system	17	40
Wetland Vegetation	Rooted swamp and marsh vegetation	15	35
Water Fowl	Resident and migrant birds using the wetland area	13	30
Estuarine Communities	Plants and animals in diluted salt-water	10	24
Freshwater Communities	Plants and animals in water less than 0.5% salt	10	23
Zooplankton	Drifting or floating animals	10	23
Phytoplankton	Drifting or floating chlorophyll plants	10	23
Upland Game Birds	All non-water birds using the area	10	23
Game Mammals	Migrant and resident mammal populations	9	21
Ocean Communities	Plants and animals in ocean water	8	19
Pests	Annoying or harmful species	6	14
Intertidal Organisms	Organisms between high and low tides	4	9

(Table D-3, Continued)

Table D-3 (Continued)

Environmental Items	Description of Item	Times Addressed	Percent
Aesthetic			
Surface Configuration	Landscape lines and forms	28	67
Aquatic Animals	Aesthetic values of apparent aquatic animals	24	57
Compatibility	Compatibility to natural characteristics	21	49
Upland Vegetation	Aesthetic quality of upland vegetation	18	42
Odor	Odors from any source	18	42
Shoreline Vegetation	Aesthetic quality of shoreline vegetation	17	40
Sounds	Natural or manmade sounds	14	33
Clarity	Visible gases, dust, suspended particles	14	33
Terrestrial Animals	Aesthetic values of apparent animal population	13	30
Planting and Site Design	Attempts to shape, landscape, or revegetate	11	26
Flow	Perceived rate of water body motion	9	21
Clarity	Suspended sediment and color	8	19
Land-Water Interface	Shoreline alignment and water level changes	3	7
Prospect	Expansiveness of typical views	2	5
Geological Surface Materials	Soil, rock, or unvegetated surface material	1	2
Composite	Overall effect on senses	0	0
Economic			
Sport Fisheries	Changes in abundance and diversity	25	60
Recreational Navigation	Change in frequency and type of commercial navigation	22	51

(Table D-3, Continued)

Table D-3 (Continued)

Environmental Items	Description of Item	Times Addressed	Percent
Commercial Fisheries	Effects of populations of commercial fish	20	47
Land Change	Change in economically usable land	17	40
Employment	Direct or indirect employment changes	16	37
Commercial Navigation	Change in frequency and type of commercial navigation	16	37
Income Generation	Income increase or decrease from a project	15	35
Beach Nourishment	Beach replenishment	14	33
Property Values	Effects on adjacent property values	12	29
Public Revenues-Expenditures	Changes from project and secondary economic activity	10	23
Building Fill	Using disposed material as building material	10	23
Dislocation of Existing Activity	Discontinuation of existing activity	9	21
Navigation	Impeding commercial or recreational navigation	9	21
Soil-Building	Using fill or dredged material for fertilizer	7	16
Water Treatment Cost	Expense of controlling turbidity, toxics, etc.	4	9
Marsh Creation	Creation or building of eroded marshes	4	9
Investment/ Decline	Economic development or decline	3	7
Public and Private Services	Movement of pipelines, powerlines, etc.	2	5
Factor Requirements	Labor, equipment	0	0

(Table D-3, Continued)

Table D-3 (Continued)

Environmental Item	Description of Item	Times Addressed	Percent
Social			
Change in Recreational Assets	Changes in hunting, boating, fishing, nature watching, etc.	30	70
Increased traffic	Greater amount of vehicles	22	51
Changes in Natural and Scenic Assets	Changes in the visual landscape	19	44
Changes in Growth Patterns	Changes in growth of population stability	14	33
Hazard Creation	Actual or potential health and safety hazards	12	28
Changes in Residential Areas	Changes in social character of residential areas	11	26
Elimination of Archeological and Paleontological Assets	Man-made structures showing past life or development	9	21
Geographic Population Shifts	Movement of people for social, economic, or land-use changes	7	16
Changes in Socio-economic Characteristics	Changes in education, occupation, income, etc.	4	9
Changes in Community Cohesion	Change in long- or short-term cohesiveness	3	7
Changes in Community Character	Changes in community personality, life-style, etc.	3	7
Changes in Accident or Illness Rate	Change in rate of illness or accident	2	5

(Table D-3, Continued)

Table D-3 (Concluded)

Environmental Items	Description of Item	Times Addressed	Percent
Psychological Effects of Environmental Changes	Changes in characteristic behavior pattern	1	2
Changes in Social Activity Patterns	Changes in shopping, recreation, visiting, etc.	1	2
Changes in Educational Assets	Use of project features for educational purposes	1	2

Table D-4. Reported testing in EIS's by project type*

Tests	Project Types			
	Property Protection	Site Dev.	Poll. Control	Dredging and Filling
Biological analysis	3	1		1
Sediment analysis	5		1	4
Water analysis	2	1		3
Turbidity	1	1		1
Well monitoring			3	
Total organic carbon	1			
Gradation analysis	2			1
Fish surveys	2			1
Bioassay			1	1
Elutriate	1			1

* The reported tests were conducted in 18 of the 42 EIS's reviewed.

In summary, regarding the review of the 42 environmental impact statements, the following points are relevant

1. Several of the water-quality items mentioned in the impact statements were merely acknowledged rather than assessed for potential environmental impact. For example, turbidity was the environmental item mentioned most frequently (86%), but actual turbidity levels were given on only 24% of the statements mentioning turbidity. Further, just 3 of the 43 statements reviewed indicated specific testing for turbidity.
2. Only 37% of the impact statements prepared since 1972 addressed Sec. 404 by name. Of this percentage, few statements went beyond stating that Sec. 404 granted the authority to perform a particular activity in navigable waters. No reviewed statement mentioned specific procedures for compliance with Sec. 404 procedures and guidelines.
3. Testing was another area where deficiencies existed. Only 18 of the 42 EIS's reviewed included any testing in their evaluation. The elutriate and bioassay tests recommended by the Environmental Protection Agency (Federal Register, Vol. 40, No. 173, 5 September 1975) were conducted for just 2 of the 42 statements reviewed.

Permits/Statement of Findings

A total of four permits and seven Statements of Findings were reviewed. The review process was similar to that utilized in the environmental impact statement review; namely, each document was read separately by two individuals, and a worksheet was completed for each permit/Statement of Findings. The distribution according to project type and location is as follows:

Type of Project	Number of Permits/Statements of Findings Reviewed
Site development	4
Property protection	5
Dredging and filling	2

Location	Number of Permits/Statements of Findings Reviewed
Delaware	2
Florida	3
Illinois	1
Iowa	1
Mississippi	1
Montana	1
Ohio	1
Oregon	1

Table D-5 contains a summary of the impacts that were mentioned in the 11 permits/Statements of Findings subjected to review. The most frequently mentioned impacts were as follows:

Physical/Chemical - Turbidity (55%)*
Suspended solids (18%)
Toxic materials (18%)

Ecological - Fish (55%)
Benthos/epibenthos (27%)
Wetland vegetation (27%)

Aesthetics - Aquatic animals (36%)
Shoreline vegetation (18%)
Man-made structure compatibility (18%)

* Number in parentheses denotes % of the 11 reviewed permits/Statements of Findings which addressed the stated impact.

Table D-5. Summary of review of selected permits and Statement of Findings

Environmental Items	Description of Items	Times Addressed	Percent
Physical/Chemical			
Turbidity	Light reduction due to suspended materials	6	55
Toxic Materials (Water)	Heavy metals and synthetic organic materials	2	18
Suspended Solids	Sediment concentrations in a water course	2	18
Flow Patterns	Current patterns, flow velocity, discharge, and water level	1	9
Nutrients	Phosphorus, nitrogen, and carbon	1	9
pH	Intensity of acid or alkaline conditions	1	9
Flood Hazards	Hazards imposed or created by flood	1	9
Erosion	Broad-scale environmental impacts on land	1	9
Ecological			
Fish	Migrant and resident fish	6	55
Benthos/ Epibenthos	Water body bottom-dwelling organisms	3	27
Wetland Vegetation	Rooted swamp and marsh vegetation	3	27
Estuarine Communities	Plants and animals in diluted salt-water	2	18
Water Fowl	Resident and migrant birds using the wetland area	2	18
Terrestrial Vegetation	Autotrophic component of a system	2	18
Ocean Communities	Plants and animals in ocean water	1	9
Pests	Annoying or harmful species	1	9

(Table D-5, Continued)

Table D-5 (Continued)

Environmental Items	Description of Items	Times Addressed	Percent
Phytoplankton	Drifting or floating chlorophyll plants	1	9
Zooplankton	Drifting or floating animals	1	9
Aesthetic			
Aquatic Animals	Aesthetic values of apparent aquatic animals	4	36
Shoreline Vegetation	Aesthetic quality of shoreline vegetation	2	18
Compatibility	Compatibility to natural characteristics	2	18
Flow	Perceived rate of water body motion	1	9
Surface Configuration	Landscape lines and forms	1	9
Land-Water Interface	Shoreline alignment and water level changes	1	9
Odor	Odors from any source	1	9
Terrestrial Animals	Aesthetic values of apparent animal population	1	9
Planting and Site Design	Attempts to shape, landscape, or revegetate	1	9
Economic			
Navigation	Impeding commercial or recreational navigation	3	27
Commercial Navigation	Change in frequency and type of commercial navigation	3	27
Recreational Navigation	Change in frequency and type of recreational navigation	2	18
Soil-Building	Using fill or dredged material for fertilizer	1	9
Building Fill	Using disposed material as building material	1	9
Employment	Direct or indirect employment changes	1	9

(Table D-5, Continued)

Table D-5 (Concluded)

Environmental Items	Description of Items	Times Addressed	Percent
Income Generation	Income increase or decrease from a project	1	9
Property Values	Effects on adjacent property values	1	9
Sport Fisheries	Changes in abundance and diversity	1	9
Social			
Change in Recreational Assets	Changes in hunting, boating, fishing, nature watching, etc.	1	9
Changes in landscape	Changes in the visual landscape	1	9
Elimination of Archeological and Paleontological Assets	Man-made structures showing past life or development	1	9
Hazard Creation	Actual or potential health and safety hazards	1	9
Changes in Accident or Illness Rate	Change in rate of illness or accident	1	9

Economic - Economic disruption (navigation) - (27%)
Commercial navigation changes (27%)

Social - No recurring impacts were noted.

Since the documents reviewed were issued in order to comply with Sec. 404, all but two of them mentioned the section specifically. Frequent mention was also made regarding measures taken, or anticipated, to comply with the administrative guidelines of Sec. 404. Only two of the permits/Statements of Findings subjected to review identified testing as a means of determining potential impacts.

In summary, regarding the review of the 11 permits/Statements of Findings, the following points are relevant:

1. Several of the impacts mentioned were merely acknowledged rather than being dealt with in a substantive manner.
2. Testing was not consistently conducted as a part of the preparation of the permits/Statements of Findings.

APPENDIX E: CASE STUDIES ON DISCHARGING FILL MATERIALS

Six case studies were selected for the purpose of more completely describing the water-quality effects of fill material discharge. These case studies were chosen based on type of project, type of fill material, and geographical location. Table E-1 contains a summary of the characteristics of the selected case studies. The purpose of this appendix is to present summary information relative to the environmental impacts of these fill discharge projects. The locations for four of the six chosen studies were visited (Kaiser Steel, Marco Island, Highway 101, and Beaumont Landfill).

Richard B. Russell Dam and Lake

Richard B. Russell Dam and Lake is located in the Piedmont Plateau in Elbert and Hart Counties, Georgia, and Abbeville and Anderson Counties, South Carolina. The damsite is located on the Savannah River about 16 miles southeast of Elberton, Georgia, about 29.9 miles below Hartwell Dam, 37.4 miles above Clark Hill Dam, and 275.1 river miles above the mouth of the Savannah River (U.S. Army Engineer District, Savannah, 1974). At this site the river flows between steep valley walls that rise from the water's edge to elevation 442 ft MSL on the left bank and 441 ft MSL on the right bank. Above these elevations gentle slopes rise to the uplands at elevations 500 to 520 ft MSL.

Description of project

The dam, which is under design, will be a gravity-type concrete structure with a length of 1580 feet at a top elevation of 495 ft MSL. The concrete structure includes a powerhouse with four 75,000 kilowatt units, and a spillway 590 feet long equipped with 10 tainter gates each 50 feet wide and 45 feet high. The concrete section will be connected to high ground on each side by rolled earth embankments approximately 2780 feet long, with a crest elevation of 495 MSL. The total length of the dam is 4360 feet.

At maximum power pool elevation (475 ft MSL), the Richard B. Russell Lake will inundate 26,650 acres (approximately 11,750 acres in Elbert and Hart Counties, Georgia, and 14,900 in Abbeville and Anderson Counties, South Carolina), and create about 546 miles of shoreline. The anticipated fluctuation in the elevation of the power pool is 5 feet. The total land require-

Table E-1. Characteristics of selected case studies

Case Study	Geographical Location	Project Type*	Location* Relative to Water	Physical Configuration*	Fill Material
Richard B. Russell Dam and Lake	Savannah River in Georgia and South Carolina	Structure and impoundment	B	Line (dam) and area (lake)	Concrete and earthfill
Kaiser Steel	Hoquiam, Washington	Site development (industrial)	A (wetland)	Area	Dredged material and quarry rock
Marco Island	Marco Island, Florida	Site development (residential and commercial)	A (wetland)	Area	Dredged material
Highway 101	Geyserville, California	Road fill	B	Line	Earthfill and highway solid wastes
Maumee Bay	Toledo, Ohio	Property protection (dike)**	A (wetland)	Line (dike) and area (dredged material disposal site)	Earthfill (dike)
Beaumont Landfill	Beaumont, Texas	Pollution control (sanitary landfill)***	A (wetland)	Area	Municipal solid waste

* See Table 2 in Part II for explanation of project type, location, and physical configurations.

** Dike surrounds dredged material disposal area; ultimate site use will be for industrial development.

*** Ultimate use is as city park.

ment is 59,260 acres; 52,260 acres are designated for lake-operational requirements, and 7000 acres for public use.

Material dredged from the Savannah River will be placed in an upland disposal site. The recommended diversion plan, while requiring a larger construction area and temporary re-routing of the river, permits the majority of the construction activities to be accomplished under dry conditions. This reduces the possibility of pollutants entering the waterway. During construction of the diversion channel for the recommended plan, a natural earth plug will be left in place at each end of the channel. The plugs will be removed after the remainder of the channel is completed in such a manner that the increase in turbidity will be minimized. Careful construction practices, including management of the discharge water from the dredge operation and the water pumped from the construction area by the use of settling basins, will be employed.

Baseline monitoring

Evaluation of the materials to be discharged indicated that they originate from areas that are sufficiently removed from sources of pollution to provide reasonable assurance that they have not been previously contaminated. In order to verify this, bulk sediment testing and elutriate testing was performed by an independent environmental consultant on samples from the dredging area and the location of the diversion channel. The major constituents considered were Hg, Pb, Zn, total Kjeldahl nitrogen, volatile solids, and COD.

Nine sediment samples for benthic analysis were collected from the middle and sides of the river along three transects in the construction area. About 2 cubic feet of well-sorted coarse sand (greater than 2 mm) was collected at each site. None of the samples contained any benthic organisms. In two samples a few fragments of snails were found. One sample contained remnants of a caddis fly tube. The coarse nature of these sediments indicated that strong currents dominate this region. No infaunal forms could withstand the grinding action of these sediments. Only epibenthic organisms such as larval forms with tubes might periodically (seasonally) occupy this habitat.

Anticipated environmental impacts

The destruction of wetlands is not significantly associated with this project since little wetland habitat will be destroyed by filling operations or inundation. However, bottom habitat will be affected where the actual dam is to be constructed. Regarding impairment of the water column, construction activities such as dredging of the sand overburden between the cofferdikes, and removal of the plugs from the diversion channel, will result in temporary localized increases in suspended solids and turbidity. The amount of suspended solids released will be insignificant compared with normal concentrations in the river caused by heavy rains. The dam, when completed, will reduce the turbidity in Clark Hill Lake. Any increases in turbidity below the Russell Dam will be temporary, and will have only a slight effect on the fishes as they will move out when turbidity increases and return to the area after the turbidity clears up. Newly spawned fishes may be affected; however, there is no evidence that significant white bass spawning occurs in the river between Hartwell Dam and Clark Hill Dam. Trout reproduction will not be affected since the existing trout do not naturally reproduce in this stretch of the river. The Savannah River is not a free-flowing stream in this section, and it is subject to extremes of water levels and velocities due to controlled releases from Hartwell Dam.

The results of the elutriate tests, based upon a ten-fold dilution*, indicated that the discharge of the dredged material would not be harmful to man, fish, game, or other beneficial aquatic life. Low concentrations of measured constituents were also found in the sediment samples. The benthic survey of the project area indicated that the project will not eliminate any significant benthic communities.

Kaiser Steel

The Kaiser Steel project is located on the right bank of the Hoquiam River at its confluence with the upper estuary at the city of Hoquiam, Washington (U.S. Army Engineer District, Seattle, 1976). This project was undertaken to develop a site for manufacturing and assembling offshore drilling platforms. Development of the 45-acre site included construction of a berm, placement of fill, and construction of a pier and marine ways in Grays Harbor and the Hoquiam River. Site development was the responsibility of the Port of Grays Harbor. Construction of the facility for the manufacture and

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* Actual dilution which would occur during the dredge and fill operations would be far in excess of the ten-fold dilution factor employed in the Elutriate Test.

assembly of offshore drilling platforms was the responsibility of Kaiser Steel Corporation.

Description of project

Site development consisted primarily of the construction of a 300-foot-long berm using approximately 125,000 tons of quarry rock around the site, and the placement of approximately 269,000 cubic yards of dredged fill material. The berm enclosed three sides of the 45-acre tract, 25 acres of which are wetlands (tidelands). At the time of the site visit the berm was essentially complete but the fill had not been placed. The fill material, primarily sand and silts, was to be provided from maintenance dredging of the adjacent Grays Harbor navigation channel. Fill settling and consolidation was to be assisted by drainage facilities. After sufficient dewatering, an overlay of unsorted (bank run) material was to be placed. The finished surface will be crushed rock.

Initially the berm will not be completely impervious. Water from the dredged fill material is expected to filter through voids in the structure. Some suspended solids will escape in this manner, although the amount will be small. Siltation along the outside perimeter of the berm is expected to reach several inches in depth at a distance up to 15-20 feet from the toe. The voids between the rock will eventually fill with settled dredged material, and the berm will then be virtually impervious.

Anticipated environmental impacts

Regarding environmental impacts, no significant alterations of the topography of the navigation channels will occur. The existing patterns of currents and sediment movement will be altered, with possible shoaling as a result. Water-quality changes will include both primary and secondary effects. The predicted primary effects as a direct result of dredge and fill operations include (1) an average increase in turbidity in the dredged material plume of 25 JTU's over background conditions, (2) a decrease in dissolved oxygen levels of 1 mg/l to 3 mg/l below background, (3) expected reduction of pH in the plume to below 7 about 50 percent of the time during dredging, and (4) expected increases in concentrations of potentially toxic substances in the water column. For example, sulfides were predicted to increase to levels between 13 and 44 mg/l compared to background levels between 1 and 4 mg/l.

Filling of the Kaiser site will result in losses of several wetland functions. Among these losses are the following:

1. Loss of food energy production and nutrient cycling which support estuary life through complex food webs and support fisheries and waterfowl resources of direct importance to man;
2. Loss of 11 acres (4.5ha) of tideflat habitat supporting various benthic invertebrates and macro-algae;
3. Loss of at least 16 acres (6.5ha) of pure sedge marsh which provides a primary food resource for mallard, pintail and greenwinged teal on the Pacific Flyway; and loss of about 8 acres (3.2ha) of other salt marsh types;
4. Loss of 45 acres (18.2ha) of habitat for numerous species of upland birds, shorebirds, and waterfowl, including important resting, feeding, and wintering habitat of waterfowl using the Pacific Flyway;
5. Loss of feeding, protection, and nursery habitat for over 30 fish species known to occur in Grays Harbor in either juvenile or adult forms; some species have significant commercial and recreational value;
6. Loss of water space for primary and secondary productivity by plant and animal planktonic species; and,
7. Loss of other functions, including retardation of siltation and erosion, assimilation of nutrients and pollutants, and conversion of solar energy.

Project completion will result in the destruction of a wetlands habitat with the attendant loss in biological productivity of the entire area. The loss due to filling 25 acres of marsh land is estimated to be 215,000 pounds dry weight per year of organic material. The annual loss in animal production is projected to be 5,400 pounds dry weight for the 25 acres of marsh.

Elimination of the tidelands will impact the fishes using these areas for feeding, spawning, and rearing of young. Also, anadromous species are expected to be adversely affected by the loss of tidal flats. The juvenile salmonoids will not be allowed the protection of the shallow water while adapting to the increased salinity, and will be forced to other areas, possibly in deeper waters, where they will be subjected to predation. Some crabs will be lost to the dredging, but the losses for the project are considered insignificant to the total crab population.

Marco Island

Marco Island is located in Collier County on the southwestern shore of Florida. It is at the northernmost extremity of the Ten Thousand Islands chain, 100 miles due west of Miami, and 10 miles south of Naples. Marco Island proper, formerly a small fishing village, consists of about 8000 acres connected to the mainland by a toll bridge on the north and another bridge generally eastward of the new areas under development (U.S. Army Engineer District, Jacksonville, 1976).

Description of project

The Deltona Corporation has purchased a total of 19,633 acres of land in and around Marco Island so that the developmental plan includes almost total development of the entire area. There are five development areas on Marco Island proper. Upon completion of the five development areas the Deltona Corporation intends to donate about 6700 acres to the state as a wildlife preserve.

The project will involve the elimination of about 2200 acres of wetlands (mangrove swamps) with up to 6 or 8 feet of fill (18.2 million cubic yards). Fill material will come from the dredging of underwater islands, bay bottoms and a proposed bay area.

The Deltona Corporation is currently providing the area with service from a water-quality laboratory with complete staff and facilities. Also, a new water treatment plant and adjacent sewage treatment plant have been constructed. Initially, however, septic tanks will be utilized until the localized area served by any given lift station reaches at least 50% completion; then central sewage collection lines and related facilities will be constructed and connected to the home sites.

Only three of the five areas requested for development have been approved. Permits were denied for two areas in April, 1976. The Deltona Corporation is currently suing the Corps of Engineers because of this decision. The principal argument is the so-called "taking" issue, which questions the power of the Corps to limit usage of lands above the tidal zone (sovereign rights) without recompense.

Anticipated environmental impacts

A summary of the significant adverse environmental impacts anticipated to result from the development of Marco Island includes:

1. Potential flooding of 50,000 people due to the location of home floor slabs only 8.5 feet above mean sea level. (One hundred year hurricane events are estimated to cause water levels up to 15 feet above mean sea level.)
2. Permanent removal of 2200 acres of mixed mangrove swamps, and loss of 735 acres of bay bottoms. Destruction of thousands of acres of valuable seagrass beds.
3. Destruction of luxuriant nursery grounds for fish and shellfish and various forms of bird life. Excellent fishing banks are located immediately adjacent to the Marco Island area.
4. Destruction of wildlife habitat utilized by the five endangered species known to be present in the Marco Island area. These species are the southern bald eagle, the brown pelican, the American alligator, the Florida manatee, and the Atlantic loggerhead turtle.
5. Destruction of the feeding area of the Marco Island rookerie, which includes parts of one permitted development area and the two proposed development areas.
6. Possible damage to inland Floridian aquifers due to large drawdowns of freshwater with resultant saltwater intrusions. Water quality deterioration from septic tank seepage; examples include increased BOD, coliforms and viruses, and decreased dissolved oxygen. Additionally, the entrophication potential of area waters will be increased.
7. Water quality deterioration in dead-end canals due to inadequate flushing.
8. Build-up of water pollutants in bay bottoms due to the presence of haloclines and density stratification.

The significant anticipated beneficial impacts of the project include

1. Gains to the local, county, and state economy in the form of increased employment, tax revenues, and tourist trade. It is estimated that by the year 2000, employment generated by the development would amount to 3600 more workers than at present, annual income would grow to $146 million, and the Collier County net annual income would increase by $2.6 million.
2. The creation of a preserve and additional park and recreational facilities which would be deeded to the state for preservation in the public interest.

Highway 101

The Highway 101 roadfill site is located in Sonoma County from 1.8 miles south of Route 128 at Geyserville, California, to 1.9 miles north of Canyon Road. The Highway 101 roadfill project was selected to demonstrate the effects of using solid wastes (wastes from construction and maintenance operations) in highway fills in an upland environment. Construction and maintenance operations associated with highways generate substantial volumes of solid wastes each year. These wastes have a potential for attraction of disease vectors, degradation of aesthetics, and creation of water and air pollution if their disposal is not accomplished through an effective management program.

Description of project

The objective of the Highway 101 project was to develop procedures and guidelines for the disposal of all highway-associated solid waste in a manner that will not adversely affect the environment. The project was specifically designed to determine the feasibility of incorporating waste materials in the non-structural part of a roadfill (Howell, 1977). This was accomplished by placing the waste material in the median or the toe of the slopes, and not under the highway surface.

Monitoring program

A monitoring program was established to determine the extent of the environmental degradation. Observation wells were located above and below the solid waste fill area. Samples were taken from the wells and analyzed for pH, temperature, color, specific conductance, COD, BOD, tannins and lignins, and sulfates. Based on these analyses there was no apparent degradation of ground water quality as a result of the placement of solid wastes generated from the maintenance and construction of highways. The fill was placed in such a manner that there was no leaching to the surface waters; therefore, it appears to be feasible to use solid wastes generated from highway maintenance and construction operations for fill without significant adverse impacts on the environment.

Maumee Bay

In 1976, the Detroit District of the Corps of Engineers was scheduled to begin utilizing a new diked disposal area in Maumee Bay for disposal of dredgings from the Federal navigation channel at Toledo Harbor, Ohio. The navigation channel is about 25 miles long, extending from deep water in Lake Erie to a point about seven miles upstream in the Maumee River.

Description of project

The new diked disposal area is a 353-acre facility located about 350 feet southeast of the channel and adjacent to the proposed Toledo-Lucas County Port Authority disposal area and the Toledo Edison disposal area (U.S. Army Engineer District, Detroit, 1976B). It is anticipated that the diked area will accommodate a 10-year maintenance dredging program. Ultimate use of the site will provide for marine operations and industrial development by the Toledo-Lucas County Port Authority.

Monitoring program

The Detroit District contracted with WAPORA, Inc. to monitor water quality and biological parameters, and identify possible effects of the diked disposal facility upon these parameters. The work was intended to provide information on possible changes in physical and chemical water quality, blockage of fish migrations and/or inhibition of historical fish spawning patterns, and suppression or elimination of aquatic populations (WAPORA, Inc., 1976). The dike itself was in place at the time of conduction of baseline monitoring.

Water quality was found to be highest at stations lakeward of the diked facility, and lowest at those influenced primarily by Maumee River water. Phytoplankton abundance was observed to be lowest at the river-influenced stations and to increase, slightly, lakeward. Zooplankton populations were rotifer-dominated in river stations, and comprised almost equally of copepods, cladocerans, and rotifers in bay-influenced stations. Abundance was fairly equal among stations on each date, with densities being generally lower at river-influenced stations (U.S. Army Engineers District, Detroit, 1976A).

Macroinvertebrate populations, measured with Hester-Dendy artificial substrates as a water-quality monitor, showed relatively high and uniform similarity between stations when data over the entire study period were considered. In most cases, faunal similarity was highest between stations which were physically nearest each other, or which experienced similar hydrographic conditions and water quality. Fish were most abundant east of the dike, especially at the station influenced by heated water discharged by a power plant. Many young-of-the-year fish, and adult fish in spawning condition, were found east of and near the diked facility, which suggests that the area is used as a spawning ground and nursery.

A correlation analysis pointed out what was obvious from the faunal survey: the Maumee River supports a relatively sparse assemblage of organisms despite its increased nutrient load. Generally, the correlation analysis demonstrated the contrast between the river and bay ecosystems.

Anticipated environmental impacts

The diked disposal facility will cause the irretrievable loss of 353 acres of Maumee Bay bottom land and open water. Once filling begins, the diked facility may, through leaching or overflow, directly influence water quality in the area. The facility was not being filled during the monitoring program, and so any impact would have been caused by changed circulation patterns. The dike has apparently modified some patterns of distribution of organism groups, but only to a limited extent involving mostly spatial shifts.

Beaumont Landfill

For over 20 years the city of Beaumont, Texas, has used the same sanitary landfill site for the disposal of solid wastes. The 285-acre site is located in the northern part of the city. A cypress swamp is north of the sanitary landfill, and the entire area, including the landfill, is in the wetlands adjacent to the west bank of the Neches River (U.S. Army Engineer District, Galveston, 1976).

In addition to Beaumont, several small nearby cities and towns (Sour Lake, China, Nome City, and Lumberton) also use the existing sanitary landfill. At the landfill site a 2-ft subsurface layer of clay material is used; this impermeable layer is claimed to prevent leaching from the compacted solid wastes. Both the subsurface and cover material is transported about 5 miles. The present cost of disposal is about $3 per ton, with the cost of cover material being about $1 per cubic yard in place. There is some evidence of subsidence and gassing (CH_4) at the landfill site.

Since the 285-acre site is nearing capacity, direct dumping of solid waste into the cypress swamp has occurred. The Galveston District issued a cease and desist order, and the city of Beaumont applied for a landfill permit under Section 404 of PL 92-500. In the interim, the city is only using the remaining approved area for landfill, and plans to place another lift on the existing site. The existing fill is 20 feet deep and an additional lift of 10 feet will be added if permission to fill the swamp area is not granted.

Description of project

The City of Beaumont has proposed to use 135 acres of an old (1905) logged-out cypress swamp to expand their existing sanitary landfill. This swamp, which is located just north of the current landfill, is referred to as a dead swamp because of the stagnant conditions and saltwater intrusion which has resulted from prior deepening of the Neches River for navigation purposes. The ultimate use of the proposed landfill will be a new city park with attendant boating facilities. Some of the completed landfill area is presently being used by the city for a firefighting center, private boat club, and city storage area. Also, approximately 20 acres was sold to a private industry and is now used as a scrap steel storage site.

A separate but related issue is a project to build a saltwater intrusion barrier on the Neches River adjacent to the proposed landfill site. This barrier would prevent contamination of freshwater supplies by saltwater during periods of low river flow and high freshwater withdrawals. It would restore the wetland areas to freshwater conditions, and approximately 16.7 miles of the Neches River and Pine Island Bayou would be improved for swimming, boating, hunting, and freshwater fishing. This factor is one of the principal negating considerations in the decision to allow further filling of the wetland areas with solid wastes.

Immediately downstream from the present landfill is the Port of Beaumont harbor site. Seagoing vessels presently use this facility. The Port is an economic benefit to the Beaumont area and is one of the reasons that the saltwater intrusion barrier is justified.

Anticipated environmental impacts

Current pollution of the Neches River from the existing landfill is mild compared to industrial pollution sources. A pulp and paper mill upriver from the landfill has a permit to discharge 70 mgd of effluent into the Neches River. Several years ago the effluent BOD was as high as 400 mg/l, but is now down to about 15 mg/l. When the saltwater intrusion barrier is built and no routine brackish water enters the area from downstream, the paper mill will be required to transport and discharge their effluent at a point downstream from the barrier. This discharge point is also downstream from the present and proposed landfill sites.

The environmental impacts of the proposed landfill include loss of 135 acres of wetland habitat and the potential for causing water-quality degradation; however, construction of the saltwater intrusion barrier would minimize any water-quality deterioration in the Neches River.

APPENDIX F: MINIMIZATION OF ENVIRONMENTAL IMPACTS

One of the key concerns related to fill material discharge is to plan and conduct the operations in such a manner and at such selected locations that physical, chemical, and biological impacts will be minimized. This appendix is addressed to selected technology available for impact minimization. The first section delineates general planning/design concepts and constraints which can be used to preclude major undesirable environmental consequences. The second section focuses on various means of water pollution control during project construction. The engineering properties and design considerations related to the structural integrity or (in)stability of newly placed or excavated materials are presented in Appendix G.

Planning/Design Concepts and Constraints

Clark (1974) discussed environmental constraints on specific uses of coastal ecosystems and suggested that these constraints involve the following four aspects: (1) location of the proposed use, (2) design and placement of structures, (3) control of construction activities, and (4) control of operational or occupancy modes. The first two are planning functions; the second two require attention in planning, but are mostly involved with enforcement of construction specifications and performance standards.

Environmental constraints for various types of projects

Table F-1 contains a list of environmental constraints for the following projects potentially involving the discharge of fill material: airports, marinas and piers, roadways, bridges and causeways, heavy industry, solid waste disposal, and residential development (Clark, 1974). Airports have often been located in the coastal zone, either on filled areas which can be classified as on-shore areas or on man-created areas located in coastal waters. The growth of pleasure boating and recreational activities has accentuated construction of new marinas and related waterfront developments. Roadways in coastal areas not only alter lands of the road right-of-way, but may induce new forms of land use along the road corridor and, through pollution and physical disruption, reduce the quality of coastal ecosystems. It is also undesirable to construct bridges and causeways in coastal areas in such a way that interference occurs with normal patterns of waterflow. Heavy industry in

Table F-1. Environmental constraints for coastal projects

Project	Constraints
Airports	1. Coastal ecosystems are to be protected from airports by buffer strips. 2. Airports are to be located above coastal floodplains, using them as a buffer. 3. Runways and facilities are to be designed to minimize paved surfaces. 4. Runoff from the airport complex is to be collected and restored before discharge (perhaps into buffer strip vegetation).
Marinas and piers	1. Marinas are to be located in naturally protected harbors with steep shores where the least amount of alteration of vital areas is required. 2. Water basins with poor flushing are to be avoided as marina sites. 3. Supporting marina facilities, such as winter storage yards, are to be located inland. 4. Impervious surfacing on the waterfront is to be avoided to the maximum extent, and effective storm drain systems are to be installed. 5. Pilings are to be used to elevate marina structures rather than solid fill. 6. Pump-out facilities for boat sewage must be provided.
Roadways	1. Major roadways are to be located above the coastal floodplain. 2. Roadways built in coastal watersheds shall be designed and located so as to prevent pollution of runoff water or interference with natural drainage patterns. 3. Major roadways within the coastal floodplain are to be located parallel to land drainage flow (generally, perpendicular to the coast). 4. Essential minor roadways are to be designed to facilitate the flow of land drainage and coastal waters. 5. Essential wetland, tideland, and estuarine crossings are to be built as elevated structures.
Bridges and causeways	1. Bridge structures are to be designed so as not to impede or reduce the natural volume or rate of flow of water. 2. Causeways through wetlands, tidelands, or estuarine basins are to be elevated with piers or pilings rather than fill, and segmental construction is to be used.

(Continued)

Table F-1: Concluded

	3. Extreme care is to be taken to reduce soil discharge and other disturbances during highway construction.
Heavy industry	1. Industries not wholly dependent upon waterfront location are to be placed inland. 2. Industries are to be located so as not to preempt or endanger vital areas. 3. Assessments of the impact of a proposed site are to include the secondary development induced by the industry. 4. Pollution control standards are to be strictly enforced. 5. All general land and water use constraints set forth in Clark (1974) are to be followed.
Solid waste disposal	1. Solid waste disposal sites are to be located out of coastal floodplains, wetlands, tidelands, and water area. 2. In coastal watersheds, locate solid waste disposal sites away from waterdrainage courses, well above the high groundwater level, and so as not to interfere with normal drainage flow patterns.
Residential development	1. In shorelands above the coastal floodplains, normal precautions are required to prevent interference with the natural pattern of drainage and to prevent contamination of runoff water. 2. In the coastal floodplain, special precautions are required to protect drainage flows and to prevent pollution of coastal waters through contaminated runoff; development density will be at a lower level than in upland areas. 3. Vital areas such as wetlands, tidelands, sand dunes, and drainageways are not to be converted to residential use. 4. All constraints on development set forth in Clark (1974) are to be respected, as appropriate, in the planning, location, construction, and occupancy of coastal communities.

After Clark, 1974.

coastal areas can produce several types of adverse environmental impacts including preemption of coastal vital areas, impacts from extensive secondary development induced by the presence of industry, and generation and discharge of air and water pollutants and domestic sewage. Proper site selection and provision of adequate design factors will preclude the undesirable impacts of the land disposal of community solid wastes on coastal water quality. The process of residential development in coastal areas involves a complex of potential ecologic disturbances to coastal waters, both from the construction activity and from human occupancy and ancillary development activities.

Additional constraints for wetland area projects

Additional recommended constraints for construction and operation of marinas in marshlands have been developed (Giannio and Wang, 1974). This study recommended providing a flushing mechanism to remove nutrients, increase dissolved oxygen, and inhibit stagnation. They also recommended that dredged material not be used for landfill for marinas because of concern regarding the chemical constituents and potential leaching which might occur. Further, the marinas should incorporate positive methods of liquid waste collection and treatment to minimize any liquid waste introduction into coastal waters as a result of human activity.

Marcellus et al. (1973) identified several criteria for determining when filling may be justifiable in Virginia wetlands. These criteria are delineated in Table F-2 along with some additional constraints relative to filling practices and impact minimization. Table F-3 contains information on various policy and development constraints associated with the construction of bulkheads and groins in the coastal zone. Essentially the same considerations as delineated in Table F-3 are also applicable to breakwaters and jetties (Marcellus et al., 1973).

Constraints for special cases

Proper planning/design practices have been developed to minimize the impact of water drainage from highway fills (Clark et al., 1974). The objectives of the reported study were to determine the conditions that lead to fill slides on highways in Kansas and to develop means of preventing or halting such slides.

One means of positive control of leachates which might be generated as a result of the discharge of fill material is through the use of liners. For example, Dvorak et al. (1970) reported on the use of plasticized sheets as impervious membranes for the sealing of earth dams. Numerous liner

Table F-2: Criteria for wetlands filling

Criteria for determining if filling may be justifiable:

a. The filling will result in definite and significant benefits to the public at large.

b. Only wetlands of minor ecological value are to be lost.

c. All other alternatives have been rejected because of ecological reasons.

Wetlands filling should be viewed critically when:

a. Wetlands of primary as well as high secondary ecological significance are threatened.

b. Wetlands are to be filled to extend or create waterfront homes or sites for which upland sites would be more suitable. These include proposed uses such as buildings, parking areas, or commercial recreational facilities when there is little apparent benefit to be gained by the public at large.

c. Wetlands are to be used simply as disposal areas for refuse or dredged material.

If filling is justified, the following precautions will help minimize the damage:

a. All material should be retained by dikes to prevent damage to adjacent land and water areas. There should be a buffer strip between the dikes and the outer limits of the proposed fill especially when the area to be filled is soft.

b. The outside of the dike banks and the top of the dike should be vegetated as soon as possible to prevent erosion of sediments into adjacent waters or marshes.

c. The capacity of the disposal area, the rate of filling (i.e., discharge volume from hydraulic dredging operation), and the dimensions of the spillway should be such that only sediment-free water is allowed to flow back to adjacent waters. There must be provisions for preventing the discharge waters from eroding the land, shoreline, or stream bed.

d. Upon completion of filling, the new surface should be conditioned by adding fertilizer, lime, mulch, or topsoil as needed so that seeding operations will be successful.

After Marcellus et al., 1973

Table F-3: Criteria for bulkheads and groins

Criteria for determining if these structures may be justifiable:

a. Erosion is a definite threat to buildings, roads, or other installations and vegetation either doesn't exist or is insufficient to provide the necessary protection.

b. The construction is part of an approved marina or waterside facility and there is no other way, such as open-pile type structures, upon which to place the necessary services to prevent fill material from entering the water, or to protect watercraft from wind and wave action.

c. Existing channels are threatened by excessive deposition which cannot be controlled by other means.

d. Safe navigation in the public interest requires sheltered channels.

Construction of these structures should be viewed critically when:

a. There is no significant public benefit.

b. The purpose is to create "usable" land by filling in wetlands for purposes not directly connected with essential marine uses and for which upland areas could or should serve as well or better.

c. The construction will result in cutting off wetlands from tidal waters.

d. Evidence suggests that adjacent lands and aquatic areas, public or private, are in danger of being severely affected by the structure.

It is important that shoreline defense structures be designed relative to the conditions of the particular location they are intended for. Some questions which can be asked in regard to this include:

a. Is the proposed structure adequate for the purpose it has to serve?

b. Will the structure adversely affect other shoreline areas? That is, is there sufficient evidence that the structure is so designed and placed that it will not cause erosion elsewhere?

c. Will useful and important public bottoms be encroached upon or otherwise adversely affected? If so, is the adverse effect permanent, temporary, or can damages be ameliorated or compensated?

After Marcellus et al., 1973.

materials are beginning to be utilized for controlling the leachates generated from sanitary landfills. Use of liners for leachate control will probably increase in the future due to greater emphasis on sanitary landfill impact minimization.

The use of dredged material for the creation or enhancement of marsh lands has received increasing attention within the last several years (Johnson and McGuinness, 1975). For most of these marsh-creation projects, the regularly flooded salt marshes are of primary interest. Johnson and McGuinness (1975) developed several conceptual planning and construction guidelines to alleviate the physical impacts of newly created marshes. These guidelines are summarized in Table F-4.

One of the direct effects of marsh creation with dredged material is smothering of the substrate. It may be possible to mitigate adverse biological impacts in highly productive shellfish, plant community, or spawning areas by removing the existing biological resources prior to disposal. For example, high-value oyster beds could be harvested for market or removed and placed in another area. Short-term turbidity problems can be minimized by providing silt curtains or other operational aids. Longer term turbidity problems can result from resuspension of fine-grained materials through wave action. The effects of long-term turbidity increases can be reduced by placing coarse-grained sediments on top of the finer materials to provide an armor against wave attack (Johnson and McGuinness, 1975). Revegetation of dredged material disposal areas is another technique to reduce adverse impacts.

Construction/Erosion Control

Construction sediment has long been recognized as a significant source of water pollution; however, until the passage of the 1972 Federal Water Pollution Control Act (PL 92-500) there was little effort to determine the nature and extent of this problem (Ross, 1974). Pollutant-producing operations during project construction include clearing, grubbing, fill discharge, pest-control, rough grading, facility construction, and after-effect restoration necessitated by staging, stockpiling, and borrow pit leveling. About two-thirds of the sediment loads in surface water courses are associated with man-induced activities such as construction.

Table F-4: Guidelines for alleviating physical impacts of newly created marsh on the environment

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Direct Impacts

- Place dredged material on habitats of low biological value.

- To prevent the spread of fine-grained dredged material as density currents and for the control of turbidity:

  - Use existing island and bottom topography to help confine materials.
  - Use coarse-grained material on exposed surface of the fill.
  - Use silt curtains in low water energy areas.
  - Dike the disposal area.

Indirect Impacts

- Do not block natural drainage channels and waterways with dredged material, since isolation of large areas could result.

- When building a marsh near to or directly adjacent to an existing marsh, avoid cutting off water circulation. This can be accomplished in the following ways:

  - Ensure adequate channel capacity for water circulation.
  - Control the final elevation of the fill so that normal tidal circulation can flow over the fill and the existing marsh.

- When disposing of material near or adjacent to inlets and other tidal channels, carefully evaluate possible reduction in hydraulic capacity in relation to tidal prism.

- When disposing of dredged material near shore, consider the potential for changes in the predominant pattern of littoral drift and wave refraction patterns.

- In all cases, carefully evaluate the potential for reducing wind fetch and thereby reducing the wave-energy regime which controls movement of sediment.

After Johnson and McGuinness, 1975.

Methods to minimize construction impacts

A recent EPA report (1973) summarized methods which are available for minimizing construction phase impacts. The principles of proper erosion control include minimizing soil exposure, controlling runoff, shielding the soil, and binding the soil. Minimizing soil exposure involves the staging of fill discharge, grading, and revegetation so that a minimum of soil surface is exposed at any one time. Runoff is controlled through interception, diversion, and proper disposal. It may also be controlled by decreasing the amount of runoff through special grading practices and the staging of construction activities. To shield the soil surface from the impact of raindrops and from the scouring effects of both overland and channelized runoff flow, various surface covers of mulch or paving materials can be used. The binding of soil particles together to make them less susceptible to removal by rainsplash or runoff is accomplished by using both chemical and natural binders. Natural binders include soil products such as clays and organic matter.

Erosion control practices

Most erosion control practices can be grouped under the following categories: surface roughening, interception and diversion practices, vegetative soil stabilization, and nonvegetative soil stabilization.

Surface roughening. Surface roughening practices such as scarification and the use of serrated slopes are designed to decrease the amount of runoff as well as slow its movement. These practices reduce the ability of the moving water to detach and transport soil particles. Moving a cleated dozer up and down a graded slope is another means of providing a roughened slope. This practice is referred to as "tracking" and is more adaptable to steep slopes than scarification. Surface roughening is also beneficial in the establishment of vegetation on a graded area. The horizontal grooves retain soil additives, seed, and mulch that might otherwise have been washed down the slope. This practice also increases moisture retention and loosens the soils permitting plant roots to develop more readily.

Interception and diversion practices. These are practices designed to intercept runoff before it has a chance to come in contact with an erodible fill material surface. Both diversion structures and disposal structures may be required.

a. Diversion structures. These structures include soil or stone dikes, ditches, and terraces or benches. They are used extensively at the top of graded slopes to divert offsite runoff away from the erodible surface. Diversion structures are also located on long graded slopes to reduce the amount of runoff coming in contact with the lower portion of the slopes. Interceptor dikes are a specialized variety of diversion structure. Their principle use is along graded roadway rights-of-way. They are placed across the right-of-way to intercept runoff and divert it either onto a vegetated area or into a disposal structure or sediment detention structure. The dike may be constructed with compacted soil or crushed stone or gravel.

b. Disposal structures. Runoff disposal structures are usually required to safely dispose of the concentrated runoff collected by diversion structures. Flexible downdrains, sectional downdrains, and flumes are popular means of conducting concentrated flow down a graded slope to a disposal point. The flexible downdrain consists of a metal end section connected with a flexible fabric tube resembling a large hose. Sectional downdrains are usually half-round pipes constructed of bituminized fiber, concrete, or metal. Flumes constructed of concrete or asphalt are not a commercial product. Corrugated or plain metal flumes are available commerciallly.

Vegetative stabilization. Vegetation is used both for temporary or permanent stabilization. Temporary stabilization involves the use of fast-growing annual and perennial plant material to provide interim protection, generally for a period of less than one year. When an area is to be stabilized for a period of generally more than one year, permanent vegetative soil stabilization is performed. This involves the use of long-lived perennial plant material (such as grasses, legumes, ground covers, vines, shrubs, native herbaceous plants, and trees) selected on the basis of specific site conditions.

Nonvegetative soil stabilization. As in the case of vegetative soil stabilization, nonvegetative soil stabilization includes both temporary and permanent stabilization.

a. Temporary stabilization. Temporary stabilization involves the use of various coverings and binders that either temporarily shield the soil surface from rainfall impact and runoff or temporarily bind the soil particles into a more resistant mass. Included in this subcategory of control practices are mulches, nettings, and chemical binders. Customarily, these practices are used either to provide temporary protection while a more permanent vegetative cover is developing (mulching), or to provide interim protection during grading delays or until a long-term vegetative cover can be established.

b. Permanent stabilization. Permanent stabilization becomes necessary when erosive or climatic conditions or other factors preclude the use of vegetation. Areas commonly requiring this treatment include excessively steep slopes, graded areas containing groundwater seepage, droughty or toxic soil conditions, soil surfaces in waterways exposed to high velocity concentrated flow, and shorelines receiving high energy wave impacts.

In upland areas,permanent nonvegetative stabilization usually consists of a protective blanket of coarse crushed stone, gravel, or other durable material. When slope steepness exceeds the natural angle of repose of these materials or when serious sliding or sloughing is likely, more rigid structures are required. These are usually concrete, wooden, or metal retaining structures or pavements of concrete or asphalt.

APPENDIX G: ENGINEERING DESIGN CONSIDERATIONS FOR FILL MATERIAL PROJECTS

In addition to general planning/design concepts and constraints discussed in Appendix E, specific considerations need to be given to the engineering properties of the fill material as well as design relationships for impact minimization. Examples of these properties and relationships are included in this appendix. More specifically, attention is focused on physical properties; construction in marginal lands; hydraulically placed fills; and engineering characteristics of peat, dredged material, and other categories of fill material. The last section of this appendix deals with engineering testing and associated design controls for minimizing the impacts of fill projects.

Physical Properties

Fill material, in a very broad sense, encompasses particulate matter of various sizes, as well as very large pieces with considerable mass and volume. While one end of the scale is occupied by micron clay-size particles, the other end is identified with tree trunks, brush, tires, and construction and demolition debris. In so far as constituents are concerned, fill material may be of mineral, organic, or plastic origin, or any combination of these. Thus, the engineering performance of many fill materials becomes complicated to analyze because it spans an extremely wide range of behavioral characteristics. For the most part, dredged fill material is soil particulate matter varying in size from clay through gravel and occasionally boulders. Because soil has been used as a construction material for centuries, knowledge of and experience with soil behavior is at a point that reasonably dependable predictions can be made of its performance.

The physical properties of fill material which have a bearing on engineering design are grain-size distribution, shape of individual grains, and geometric arrangement of particles. From these properties there results engineering or mechanical properties identified as compactability or densification, strength, permeability, compressibility or deformation under geostatically or externally induced stresses, and durability of resistance to weathering under variable environmental changes. The mineralogical composition of individual particles gives rise to physicochemical manifestations which affect the engineering behavior of fill materials, and thus produce not only physical but also potential chemical and biological impacts.

Regardless of the source of fill material, its placement is invariably associated with water, for example:

(1) Water is used as a medium or vehicle of placement in hydraulic fills.

(2) Water is used as a means of facilitating densification of fills.

(3) Water contents after placement may vary to the point that they affect the strength and deformation properties of the fill.

(4) Water influences the clay-water system causing either aggregation or dispersion, which in turn influences the engineering properties of the soil mass.

(5) Water plays an important role in the generation and migration of gas in waste landfills, thus affecting structural stability and safety.

Excavation and placement of fill material involves a disturbance of the soil mass with attendant modifications of its properties. The before-and-after conditions are qualitatively depicted in Figures G-1 and G-2. A property p, in the new environment, may assume a value p'. If coupled with the addition of waste material having a property q, the two materials may conjunctively have a set of properties p' + q or a new property r. To serve as an example, Mudroch and Zeman (1975) discussed the physicochemical changes resulting from the subaerial exposure of dredged material during land disposal. Selected sediments from the lower Great Lakes area were used. For post-glacial sediments and allophane clays the plasticity decreased. It was concluded that the important consequence of drying was to change plastic to nonplastic behavior; that amorphous materials, in the form of coatings, possessed viscous properties when moist and elastic properties when dry; and that the cation exchange capacity increased for post-glacial sediments. Thus it appeared that the underlying causative factor for these changes was the geomorphology of the sediments.

Inasmuch as the plasticity and possibly the aggregation tendency of sediments are modified upon movement, it is reasonable to expect attendant changes in their consolidation characteristics ; for example,

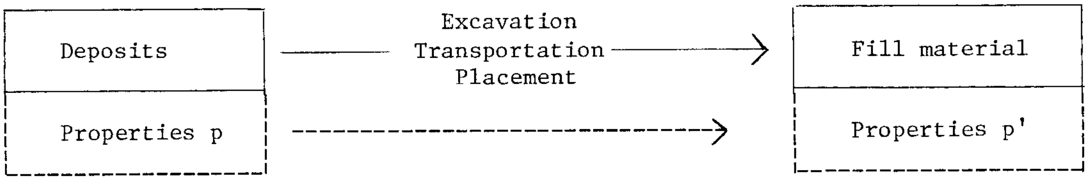

Fig. G-1: Change of properties within new environment (fill)

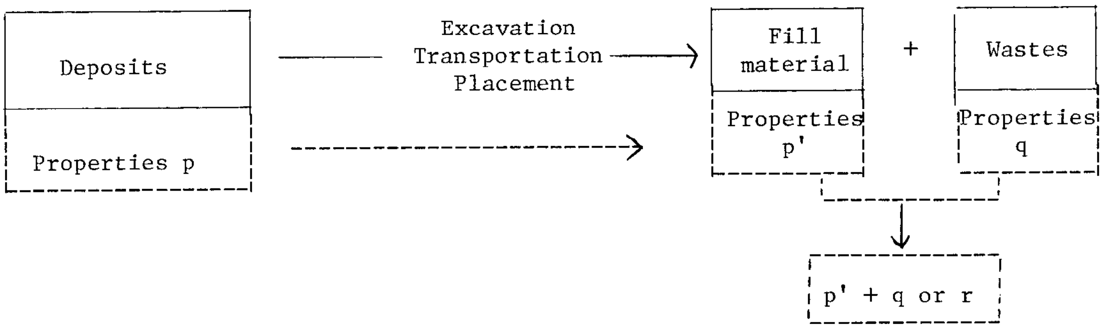

Fig. G-2: Change of properties within new environment (waste and fill)

Lacasse (1977) provides information on increases in volume. For less plastic channel sediment a volume increase of 12% was observed, while for dredged material a 25% increase was noted.

Engineering Properties and Design Considerations

Construction in marginal lands

There is an extensive bibliography on the use of fill materials in marginal lands. From this, a few references are presented to outline the present level of knowledge and identify pertinent concerns. Rutledge (1970) addressed the problem of settlement control in marginal lands used for urban development. Design procedures were illustrated by charts and examples which relate to (a) fill plus time, (b) fill plus surcharge fill later removed, and (c) fill plus surcharge plus sand drains. Secondary compressions are compensated for by increased allowances for surcharge fill and time. This is a very critical feature in organic soils. Very low shear strengths of a spongy, compressible deposit dictate that the filling operations be effected very slowly and large settlements be acceptable. On the other hand, wherever precompression by excess loading is feasible, the height of the surcharge and the time it is left in place increases substantially as the thickness of the organic stratum increases. The effect of sand drains is to accelerate the primary and secondary consolidation settlements.

Moore and Chryssafopoulos (1972) also discussed approaches to the use of marginal lands. Where substantial subsidence is expected, the authors suggested that structures be built by one of the following methods: (a) rigid design, (b) flexible design, (c) hinged or articulated design, and (d) design for maintenance. The examples and structural details given attested to the philosophy that structures act in unison with the foundation fill material. Perhaps the most striking deviation from the conventional approach was that expressed by the design for maintenance, wherein the design becomes a continuous process. For example, when the differential movement along the circumference of a tank built on soil mats placed on fill in low-lying lands becomes excessive, the tank is releveled. Such a design is inexpensive compared to a pile-supported foundation.

A similar approach using design maintenance has been effectively used by Stamatopoulos and Kotzias (1971) in the construction of an embankment on yielding sea bottoms. A stability equation was devised with a factor of safety less than 1. With proper instrumentation and measurements, early warning of failure was obtained. Construction, however, proceeded beyond the location of the first indication of failure. Simultaneously, the extent and consequences of failure were followed quantitatively. Proper modifications were made in the design and effected in the field; as a result, base failure which caused lateral and upward movement of the soft clay foundation was compensated for by adding fill material on the crest of the embankment.

A miscellaneous rubble fill dumped into soft organic silt in Flushing Bay to provide a breakwater is an example cited by Torikoglu (1966). The fill was forced down almost vertically 70 feet. However, settlement was tolerable with a two-stage construction approach. The savings realized in this project were considerable. Consequently, the example cited suggests the distinct possibility of employing this construction method in similar embankments for harbors and land reclamation projects whenever the underwater deposits are too flaccid to support fill loads.

Hydraulically placed fills

Hydraulic fills, as the name implies, contain vast quantities of water during and after placement operations are completed. Depending on the type of soil, the quantity of dilution water may vary and it is usually greater for sand and gravel than it is for silt and clay. However, in considering the hydraulic fill in its new environment, one of the requirements of acceptable performance is stability. This, in the engineering sense, has been closely associated with (a) the attainment of densities higher than those during the initial stages of placement and (b) dewatering.

Compaction methods vary for hydraulically placed fills. For example, vibroflotation, compaction piles, and vibrating probes are some of the methods utilized. Whenever rapid densification is the goal, dewatering becomes the first intermediate step to be achieved. Calhoun (1975) gave an overview of the scope of current studies in dewatering of fills in the United States and in Holland. He pointed out the dire need for developing new methodologies which are economically feasible. Electro-osmosis is a method of dewatering selected not by choice, but dictated by site conditions which make other alternatives inoperable. Sprute and Kelsh (1975) recently brought electrokinetics into new focus by referring to the case of an active mine where a hydraulically placed backfill was densified and dewatered quickly and economically.

Densification of predominantly sandy fills by compaction is discussed by Turnbull and Mansur (1973). Deposition and subsequent compaction have to be related to the water table in a way that drainage or dewatering can be simultaneously initiated. The importance of the conditions of placement are illustrated by subsequent stability failures. Some of these failures have their source in the liquefaction of the fill material.

Regardless of their potential use, hydraulically placed fills have as a basic construction requirement the selective placement of particulate matter. It is only through this placement that the fill can attain and maintain the desirable and designed stability. It is possible to cite examples wherein stability is desirable for three different purposes. In the case of marsh creation, stability refers to adequate protection against erosive forces of wind, waves, and runoff. A hydraulically filled earth dam, on the other hand, has to be protected against slope failures, wave action, and internal seepage forces. These forces could attain detrimental levels if the proper soil texture is not placed at predetermined locations within the dam. Finally, a hydraulic fill which is to carry loads imposed by structures has to maintain overall structural stability at all times.

Johnson and McGuinness (1975) outlined guidelines to be considered in the creation of marshes. Among the multiplicity of factors involved, the ones with high priority, insofar as soils are concerned, are sedimentation and clay particle behavior under various environmental conditions. These factors are discussed vis-a-vis site considerations, construction and maintenance operations, and environmentally induced energy or stresses (for example, wind and currents).

Lee et al. (1975) delineated certain problems associated with hydraulic fill dams. A dam in the San Fernando Valley which failed during the February 1971 earthquake was examined relative to post-failure soil conditions. The alluvium foundations of the dam consisted of a silty sandy gravel interspersed with lenses of clay. The same alluvial soil was used as borrow material. It was excavated and hydraulically transported and deposited to construct the dam. This process caused various degrees of material sorting. The sorting of coarse material was more distinct in the outer part of the dam than it was towards the center where the material was finer. The relative density of the hydraulic fill varied from very low values to about 60%. Inasmuch as the failure was attributed to seismic forces, the response of the soil material to cyclic stresses and its shear wave characteristics were investigated. Results of these studies revealed that the hydraulic fill, which showed normal strength behavior under static loading, dilated under cyclic loading as the result of large peak excess pool pressures being developed, and finally failed by liquefaction.

Hydraulic fills to support structural loads present a rather dismal picture, according to Whitman (1970), in that the available information is rather scant. It appears that, for a variety of reasons, engineers have generally studied the foundations supporting the fill rather that the fill itself. This has occurred despite the fact that engineering property data related to compressibility, bearing capacity, and consolidation of fill material are extremely significant. To support his contention, Whitman (1970) produced a state-of-the-art paper with emphasis on the engineering behavior of fills. Fill material is first classified and then case studies of fills derived from fairly clean sand, silty or clayey sand, stiff cohesive soils, and soft cohesive soils are presented. For each case studied, pertinent engineering data (gradation, density, and time for dissipation of excess pore pressure) are given in graphical or tabular form. The significant conclusions of the study are:

(1) Cohesionless fills which have relative densities less that 60% can be densified by vibratory techniques and can tolerate bearing stresses of 1 to 1.5 tsf associated with settlements of several inches.

(2) Cohesive fills, which tend to be very heterogeneous, require special treatment of the foundation, the pore pressures create problems, and the rate of consolidation becomes difficult to predict.

Peat and dredged material

Four cases cited above (Rutledge, 1970; Moore and Chryssafopoulos, 1972; Stamatopoulos and Kotzias, 1971; and Torikoglu, 1966) present special design approaches to constructing structures and embankments over soft deposits. Another group of soft deposits encompasses peat and dredged material. This grouping is justified by the unique behavior of these materials relative to load-settlement response and the special attention they require prior to use.

Weber (1969) described the problems associated with embankments over peat, which functionally constitutes a soil class all by itself. These embankments have been characterized by instability and large settlements on both a short- and long-term basis. Weber cited three projects and gave data obtained from laboratory and field tests. Perhaps the most significant property of peat is that it contains excess moisture, up to 750%; also, some gas may be present. As expected, the decrease in the void ratio is very large when a consolidating load of 8 tsf is applied and the time of consolidation is relatively long. The data presented suggest that the one-day test can be used to predict short-term settlements, but it fails to provide reasonable estimates of the long-term settlement. Also,it is important to note that the type of peat, fibrous or clayey, significantly influences its load-settlement response.

The extremely high compressibility of fibrous peat has also been investigated by Berry and Vickers (1975) who concluded that because the vertical permeability of peat decreases in the order of 10^3 due to surcharge loading, there is a marked reduction in the coefficient of consolidation, C_v. Therefore, peat characterization is essential but it requires tests which are different than, or modifications of, the conventional tests already established and standardized for mineral soils.

Construction over peat rarely results in total system collapse, primarily because engineers are very cautious with such designs. More commonly, however, such construction leads to large deformations occurring over a long period of time, thus rendering the system inoperable or ineffective. Such may be the case of delta levees supported by peat. This topic is treated by Duncan and Seed (1973) in connection with a berm of composted municipal waste or a mixture of composted municipal waste and dredged material. They aimed at evaluating: (a) the mechanism of stabilization and effectiveness of a compost berm; (b) the effects of a compost berm on the seepage,settlement, and stability of the levee and of the land adjacent to the levee; and (c) construction problems. The crest of most levees is approximately 10 feet above sea level, and the berm provides increased stability in the land-side slope of the levee. On the other hand, the berm may cause nonuniform settlement of the levee with attendant cracking. Thus, it appeared that the periodic addition of fill was warranted so that the water side of the slope was not made steeper as the crest was raised. The low density of compost or of the mixture of compost and sand was viewed as an advantage, especially since the addition of compost did not materially alter the permeability. The overall conclusion was that no advantage was gained by adding sand, and, therefore, compost alone would serve the purpose of berm stabilization. Nevertheless, a good drainage system is a prerequisite in order to prevent or minimize the detrimental effects of erosion and piping.

Dredged material is too soft or too fluid to be used directly. These materials can easily fall in the category of slurries containing 10 to 40% solids, by weight. The very low to zero shear strength, coupled with the low permeability of the material, gives rise to settlement characteristics which cannot be measured by the standard consolidation test. In an attempt to measure consolidation parameters, Salem and Krizek (1973) devised a special slurry consolidometer and conducted tests on samples obtained from sediments from the vicinity around Toledo, Ohio. Conventional testing was also conducted for comparative purposes. While it was concluded that the special test is more applicable and reasonable for dredged material, the results should be used with caution because of the range of variation.

Salem and Krizek (1976) further reported on the stress-deformation-time behavior of dredged material containing 40 to 200% water, by weight. There was a marked difference between the coefficient of consolidation obtained from the conventional consolidation test (0.0006 cm^2/sec) and that obtained from the slurry consolidation test (0.0001 cm^2/sec). Similarly, the difference extends to the compression index values. Comparisons between observed settlements, on one hand, and predictions based on the classical consolidation theory and the proposed mathematical model of consolidation of dredged material, suggest that the proposed model more accurately predicts the observed settlements. The key point centers around the data-based suggestion that the time needed to reach ultimate settlement in the field may be much shorter than that predicted from the conventional consolidation test. The foregoing discussions imply that dredged material can be classified as highly sensitive soils. In addition, and because the sedimentation process is expected to produce a spatial variation in the gradation of these materials, it will be important to investigate their time-dependent strength gain.

A further assertion that the conventional consolidation test may only partly be a dependable and suitable tool of settlement prediction is furnished by Vallee and Andersland (1974). In studying the field consolidation of ash papermill sludge, the authors concluded that the laboratory values of the coefficient of consolidation, C_v, were approximately four times smaller than the back-calculated field values. When the latter were used, the field settlements were in agreement with the consolidation theories of Terzaghi and others. In view of the fact that ash papermill sludges vary widely in properties, it is justifiably doubted that other ashes will behave in a similar manner.

<u>Other man-altered fill materials</u>

In the past, fill material was more or less select material. The intensified concerns over environment, energy, and depletion of material sources have led to the utilization of man-altered materials entirely as fill or in conjunction with select material. Consequently, the engineering properties of these new materials have to be evaluated in order to establish parameters for use in the design of fills. Examples of these properties include gradation, consistency, bearing capacity, shear strength, and consolidation. Evaluations of these properties have been based on the philosophy that if the test procedures and criteria are good for soils, they are good for these other materials; however, this may not be necessarily so.

The use of flyash and bottom ash as a structural fill and road base material is noteworthy. Thornton and Parker (1975) summarized the effectiveness and promising nature of flyash as a soil stabilizing agent with or without the conjunctive use of cement and lime. When flyash was compacted to dry densities of 70 to 80 pcf, it assumed unconfined compressive strength values ranging from 45 to 350 psi after aging 1 and 1230 days (3.5 years), respectively. Thus, it was observed that compacted flyash gained strength with time.

This gain was further attested by the time-dependent increase of the two-shear strength parameters. After 28 days, field samples attained a cohesion of 67 psi and internal friction of 43 degrees.

Joshi et al. (1975) presented similar data indicative of the beneficial use of flyash. The values of cohesion and internal friction increased from 5.2 psi and 29 degrees to 170 psi and 45 degrees, respectively, in 28 days. Their more important findings related the low compressibility of flyash under ordinary loads and its self-hardening properties. They suggested that the lower compacted density of flyash as compared to the conventional fill makes its use advantageous over soft and compressible ground.

In discussing the use of bottom ash as an engineering material, Seals et al. (1972) compared it rather favorably to sand. While the tested bottom ashes had maximum dry densities varying from 85 to 116 pcf, with corresponding optimum moisture contents from 14 to 26 percent, their permeabilities were of the order of 10^{-3} cm/sec and their internal angle of friction was 40 degrees on the average. For low stress levels, the compressibility of the bottom ashes was comparable to that of sand placed at the same relative density.

In presenting the case of waste utilization, Gray (1970) discussed compacted sewage ashes which did not swell, slake, or lose their strength upon soaking as evidenced from data based on freeze-thaw durability tests. For example, a sewage ash containing 42 percent water at a density of 63 psf had an unconfined compressive strength of 10.9 tsf after 5 cycles of freeze-thaw. However, Gray pointed out that sewage ash may be corrosive towards metals, thus precluding their uses over peat deposits where low pH waters are present.

Nelson and Allen (1974) and Forsyth and Egan (1976) concluded that, as a fill material, sawdust was workable above the water table in that it could reduce the weight of a potential slide by 71 percent, and that the fibrous intertwining of the sawdust particles caused a lateral distribution of loads.

In 1972, Pettibone and Kealy suggested mine tailings as a good, dependable material with which to build embankments. Mine tailings with various grain-size distributions were hypothetically used in embankment construction having several geometries. In studying silt-size tailings (slimes), Hamel and Gunderson (1973) emphasized the shear strength characteristics. The high strength, which is attendant to high density, is attributed to particle interlock and to the attractive electrical forces between layer lattices. With increasing degree of saturation, the surface ions hydrate and a reduction in shear strength is experienced.

Testing and Design/Construction Controls

To control or mitigate the impacts of fill discharge activities, manipulation or treatment of the material and/or appropriate design and construction procedures which compensate for the adverse or substandard properties of the material may be required. In addition, another dimension of control is related to the technique of analysis to which the material is subjected. The various tests which have been used have been standardized on the basis of past experience with soils. In determining the engineering properties of various fill materials it may be important to use additional or modified testing procedures. Tests which specifically apply to fill material, and which should be considered additional to conventional tests are: (1) seismic tests to determine the effect of cyclic loading on the liquefaction potential of hydraulic fills, (2) slurry consolidometer tests, and (3) tests to evaluate pressure and volume relationships under which the fill material will be handled and utilized.

Design and construction controls include special foundation systems or special approaches/criteria to accomodate settlement and increase the bearing capacity of fill material. Among others, they include:

(1) Use of rigid or flexible foundations.

(2) Precompression of the fill.

(3) Use of surcharge loads to reduce the long-term settlement of fill.

(4) Use of sand drains.

(5) Use of drainage systems to control surface runoff or seepage.

(6) Periodic addition of fill material to compensate for settlements.

(7) Control of the water table.

(8) Use of light-weight compaction equipment so that the fill does not fail in shear during construction compaction.

(9) Use of special compaction processes such as vibroflotation.

(10) Use of electrokinetic or electro-osmotic drainage or compaction.

(11) Use of modular construction to control shore stability, including interlocking revetments, revetment mattresses, precast permeable groins, perforated breakwater structures, or polypods.

(12) Use of available coarse-grained materials to protect exposed surfaces from the effects of weather elements.

(13) Placement of final grade of protective run so that the drainage of rainfall runoff and wave overwash will be towards the interior of fill.

(14) Stabilization of fill materials by use of vegetation, or else provision of runoff gullies to control erosion effects.

(15) In the case of peat foundation, limitations on fill activity during dry seasons and the exercise of care to not disturb the peat material.

(16) Limitations on the size of the fill with respect to the specific location such as estuarine bays, river delta sites, and streamflow encroachments patterns.

(17) Limitations on the shape and elevation of the fill to account for the anticipated erosion effects, bottom topography, required diking, transport distance, and future surface contouring efforts.

(18) Exercise of judgment in permitting fill material in bay shoal areas or primary and secondary channels so that hydraulic unbalance such as scour, siltation, and inlet closure do not intensify.

(19) Location of fill areas away from zones of active deposition, prevailing winds, major tidal currents, uncontrolled inlets and headlands where wave energy is concentrated.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Canter, Larry W

An assessment of problems associated with evaluating the physical, chemical, and biological impacts of discharging fill material / by L. W. Canter ... [et al.], School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, Oklahoma. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1977.

xii, 121, [103] p. : ill. ; 27 cm. (Technical report - U. S. Army Engineer Waterways Experiment Station ; D-77-29)

Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under Contract No. DACW39-76-C-0128.

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TA7.W34 no.D-77-29